Effectiveness Monitoring

Committee

CA Board of Forestry and Fire Protection

Full Proposal

Date Submitted: 07/23/2025

Project Title: Evaluating Fuel Hazard Reduction Effectiveness under 14 CCR § 1051: A Decision-Support Framework Using QUIC-Fire and Real-World Treatment Data

Project # (leave blank; to be assigned by EMC):

Principal Investigator(s):

Bjorn Brooks, PhD, CARBON SOLUTIONS LLC ("CARBON SOLUTIONS")

Rodman Linn, PhD, University of California San Diego (UCSD) & Los Alamos National Laboratory (LANL)

Richard Middleton, PhD, CEO, CARBON SOLUTIONS

Amy Jordan, PhD, CARBON SOLUTIONS

Carl Talsma, M.S., CARBON SOLUTIONS

Affiliation(s) of PI(s) and Address(es): CARBON SOLUTIONS, [redacted]

Societal Computing and Innovation Lab (SCIL), San Diego Supercomputer Center, University of California San Diego, [redacted]

Los Alamos National Laboratory, [redacted]

Applying Organization: CARBON SOLUTIONS

Primary Contact Phone Number(s): [redacted] (Bjorn Brooks, PI), [redacted] (Monica Hernandez-Lara, Director of Business Management, CARBON SOLUTIONS)

Primary Email Contact(s) of PI(s): [redacted]

Name(s) and Affiliation(s) of Collaborator(s):

Executive Summary

Overview

This project will develop a **decision-support framework** for assessing the effectiveness of **fuel hazard reduction treatments conducted under California Forest Practice Rule (FPR) 14 CCR § 1051**. By leveraging the QUIC-Fire modeling system and real-world treatment data from CAL FIRE's FRAP database, the project will produce empirically-validated fire behavior assessments to guide landowners, Registered Professional Foresters, and CAL FIRE planners in implementing effective, FPR-compliant fuel treatments. The Effectiveness Monitoring Committee (EMC) will benefit through measurement of risk reduction in fuel hazard pre- and post- § 1051 fuel hazard reduction treatment.

Objectives

- **Validate model effectiveness** by simulating fire behavior for historical § 1051 projects using QUIC-Fire and comparing results with observed wildfire outcomes (where and if available).
- **Forecast fire behavior** for **active and planned § 1051 treatments**, helping land managers understand likely post-treatment fire dynamics.
- **Aggregate findings** to assess treatment effectiveness across regions, forest types, and treatment prescriptions.
- **Deliver a flexible, practitioner-ready decision-support products** to guide future implementation of § 1051 fuel hazard reduction strategies including PDF decision-support documents, an interactive and predictive § 1051 treatment map, and stakeholder briefings.

Approach

- Identify **completed § 1051 projects** using CAL FIRE's FRAP Fuel Reduction Projects layer and CalTREES records.
- Select well-documented **sites with post-treatment fire occurrence** and, where possible, pre- / post- treatment **LiDAR-derived canopy structure data**.
- Run **QUIC-Fire simulations** under recorded weather and fuel conditions to **validate modeled outcomes**. Based on burn severity and stand structure changes as measured through LiDAR (where available), Synthetic Aperture Radar, and NDVI metrics.
- Simulate **future wildfire behavior** for current/planned § 1051 projects to forecast treatment performance and provide feedback on § 1051 efficacy.
- Develop and disseminate practitioner-ready decision-support products, including interactive maps of risk and effectiveness and a FPR § 1051 fuel treatment reference tool.

Project Description

Project Duration

3 years (36 months)

Background and Justification

This project is focused on evaluating the effectiveness of fuel treatments permitted under **California Forest Practice Rule 14 CCR § 1051**, which authorizes **Modified Timber Harvest Plans (THPs)** specifically designed for **fuel hazard reduction**. Our objective is to determine whether treatments conducted under § 1051 improve forest wildfire resilience and support forest adaptation to climate stress, in alignment with **Critical Monitoring Question 12(a)**.

Under **SB 901**, California committed over $2.7 billion to wildfire resilience and fuel reduction. While this investment has enabled large-scale implementation of treatment projects, the question of **effectiveness under specific regulatory programs—such as § 1051—has not been fully tested**. This project directly supports EMC's mission by evaluating whether § 1051-compliant treatments are reducing fire intensity and promoting post-treatment forest health, particularly in the face of drought, bark beetle mortality, and extreme weather events.

Landowners and registered professional foresters currently lack **a structured way to evaluate treatment performance** under this regulation. Our approach will use an ensemble of completed § 1051 treatments from the **CAL FIRE FRAP database**, linked with **CalTREES records** to establish treatment boundaries, silvicultural prescriptions, and implementation status. Remote sensing products (NDVI, SAR), **LiDAR-derived canopy metrics**, and modeled fire behavior from **QUIC-Fire** will be combined to validate ecological outcomes and fire resilience on treated lands.

This work is **distinct** from other major efforts in California wildfire modeling:

- The **USFS Missoula Fire Sciences Lab (e.g., Dr. Mark Finney's work with FSim and FlamMap)** focuses on **strategic landscape-level fuel breaks** and optimizing treatment block locations for large-scale spread reduction. This USFS effort implicitly makes assumptions about the efficacy of treatment often without considering the specifics of treatment protocols, as the modes that are being used for this work are not capable of representing the structural differences (which trees are removed, which heterogeneous tree patterns are left, what limbing is done) between one treatment protocol and another. Because we are using QUIC-Fire, we

are using meter-scale 3D resolved forests which can explicitly represent specific tree or even partial tree-scale management actions. Thus, our project instead evaluates **real, regulatory-bound treatments** such as those already implemented on-the-ground--**not theoretical options that could be considered**--and focuses on resilience rather than only spread or suppression time.

- The **UC Berkeley Stephens Lab** conducts **long-term field monitoring of prescribed fire treatments** in Sierra Nevada ecosystems. While their work provides valuable empirical insight, it is **not focused on validating the outcomes of FPR § 1051-specific mechanical treatments**, nor does it pair modeling with statewide administrative datasets.

This proposal addresses EMC needs by:

- Staying fully within the scope of the **Forest Practice Act**, focusing only on § 1051-permitted treatments (e.g., shaded fuel breaks, thinning).
- Offering a **practical tool for landowners and foresters** to evaluate past and future treatment outcomes, supported by mapped data and site-specific resilience metrics.

Through this tightly scoped, regulation-driven project, we aim to support more **cost-effective**, **compliance-aligned**, and **ecologically resilient** treatment planning across California's non-federal timberlands.

Objectives and Scope

California's Forest Practice Rule 14 CCR § 1051 is designed to enable landowners to reduce wildfire hazard while maintaining forest health through a regulated, environmentally sound process. These Modified Timber Harvest Plans (THPs) allow for fuel hazard reduction harvesting on nonfederal and privately managed parcels between 5 and 2,500 acres, and where the primary treatment objective is fuel hazard mitigation, not stand-replacing or even-aged timber harvest. This research project will evaluate the real-world effectiveness of historical and planned § 1051-compliant treatments by modeling fire behavior on treated parcels and using remote sensing tied to field-aligned observations.

The § 1051 regulation ensures well-defined silvicultural and operational guidelines:

- **Selective thinning** is required, with **dominant and co-dominant trees retained**, unless necessary for fire spacing.
- Even-aged management and regeneration harvests are prohibited.

- **Minimum post-harvest stocking standards** must be met, with fuel and vegetation managed to reduce **crown scorch or consumption**, **rate of spread**, and **fire intensity**.
- Other restrictions, such as soil disturbance, road construction, and timeline are also defined.

For this study, a prototypical § 1051 parcel might include a 500-acre, privately owned, nonindustrial forest parcel zoned as Timber Production Zone (TPZ) with:

- A prescription for shaded fuel breaks and ladder fuel thinning.
- 25-35% of basal area of the existing overstory tree canopy would be removed through selective harvest.
- No broadcast burning or clearcutting, only mechanical thinning using low-impact equipment.

To further understanding of the efficacy of fire hazard mitigation through the implementation of § 1051 in California's nonfederal, privately managed forests, this study has the following primary objectives:

- Utilize fire modeling to **evaluate the effectiveness** of § 1051 treatments in reducing fire behavior relative to untreated conditions.
- **Quantify the modeled post-treatment changes** in fire intensity, rate of spread, and canopy consumption and scorch potential
- **Validate stand fuel hazard changes** using remote sensing (LiDAR, SAR, NDVI) and post-treatment field observations (where available).
- **Characterize forest recovery** and structure over time on treated parcels, using satellite-derived time series (e.g., SAR, NDVI).
- Develop and disseminate practitioner-ready decision-support products, including interactive maps of risk and effectiveness and a FPR § 1051 fuel treatment reference tool for registered professional foresters, and agency planners.

The key metrics for use in evaluating FPR § 1051 effectiveness in the study, as measured through treatment and non-treatment simulations in QUIC-Fire, will be:

- **Fire intensity** in treated vs. untreated modeled scenarios.
- **Rate of spread reduction** (m/min or ft/min).
- **Crown fuels scorch or consumption.**

This framework will allow landowners and forest managers to identify where § 1051 treatments have succeeded or need adaptation, prioritize future treatments, and improve compliance with California's FPRs. It provides the quantitative evidence and practitioner tools needed to ensure that SB 901 funding and § 1051 permits are translating into measurable, risk-reducing forest outcomes.

Project Deliverables

This project will generate a set of concrete, regulator- and practitioner-friendly deliverables that assess the effectiveness of fuel hazard reduction under 14 CCR § 1051 and also guide informed decision-making. These deliverables are designed to serve the dual goals of (1) validating forest wildfire resilience outcomes and (2) supporting forest managers and landowners with decision-ready guidance.

Deliverables:

- A downloadable, easy-to-integrate**, SQLite database** of real-world § 1051 treatment outcomes with quantified fire behavior metrics.
- A GIS stack of data layers relevant to assessing § 1051 treatment.
- An **interactive map** tool displaying both historical and forward-looking modeled fire behavior results for § 1051 parcels.
- A **PDF decision-support document** that integrates spatial data, modeled outcomes, and regulatory guidance.
- One or more peer-reviewed publications or technical reports documenting the findings.
- Stakeholder briefings (in-person, virtual, recorded) and briefing materials for practitioners (pdf guides).

Each deliverable in the Table 1 timeline below is linked directly to EMC's goals for monitoring Forest Practice Rule effectiveness, with a focus on management relevance, practical usability, and transparency of methods and data.

Deliverable	Description & Management Relevance	Format & Distribution
Stakeholder Engagement Trips (3)	In-person briefings and feedback sessions with CAL FIRE, landowners, CPUC Fire division, and RPF networks. Ensures results are practical and increase FPR-aligned fuel treatment adoption.	Trip reports and presentation decks; **meeting notes shared** with EMC and collaborators.
Input-validated QUIC-Fire Simulation Ensemble	Set of calibrated QUIC-Fire runs for representative § 1051 treatment types across forest types. Includes validation of fuel inputs using LiDAR/SAR/NDVI post-treatment data and comparison with fire severity maps where available.	Shared as a **compressed file package** with JSON/XML simulation inputs/outputs and summary tables.
Interactive Map Tool	Web-based viewer (built with Leaflet or equivalent) displaying past and future § 1051 treatment areas with choropleths of modeled fire intensity, crown fire risk, and vegetation recovery. Offers export and reporting functions.	**Public web tool** hosted by CARBON SOLUTIONS or partner agency; downloads include shapefiles and maps.
Peer-Reviewed Publications / Technical Memos	At least two written outputs: one publication on validation framework, one memo on § 1051 treatment effectiveness. Builds scientific legitimacy and supports future funding/policy.	Published in open-access journal or hosted on project website; also shared with EMC committee.
Decision-Support Framework	Practitioner-ready toolset with step-by-step guidance for selecting and implementing effective § 1051 treatments by forest type. Integrates simulation results, regional data, and FPR compliance logic.	Distributed as a **technical guidance document PDF**; integrated summaries within the map tool.

Table 1. List of Deliverables

Project Timeline

This project will accomplish a targeted set of deliverables that translate technical findings into actionable tools and insights for California landowners, foresters, and the Effectiveness Monitoring Committee (EMC). Deliverables include practitioner-ready decision-support products to guide future implementation of § 1051 fuel hazard reduction strategies including PDF decision-support documents, an interactive § 1051 treatment map showing the predicted effectiveness and wildfire risk of treated parcels, and stakeholder briefings on learnings and geospatial products. Table 2 below provides a detailed overview of this project's planned goals.

#	Deliverable	Due	Format & Output Type
1	Stakeholder engagement trip	Y1–Q1	Presentation materials
2	Fuels treatment layer stack	Y1–Q2	GeoPackage & QGIS Project File (.qgz)
3	QUIC-Fire data inputs	Y1–Q3	Shapefile, raster, and CSV formatted for simulation
4	Stakeholder engagement trip	Y2–Q2	Report + Presentation materials
5	QUIC-Fire simulation ensemble	Y2–Q3	Archive of model inputs/outputs
6	SQLite database of § 1051 treatment outcomes	Y3–Q1	Downloadable SQLite DB + documentation
7	Interactive map viewer	Y3–Q2	Web map tool with export functions
8	Stakeholder engagement trip	Y3–Q3	Briefing materials and discussion summary
9	Decision-support framework	Y3–Q3	PDF technical guidance document
10	Peer-reviewed publication and/or memo	Y3–Q4	Published or web-hosted PDF

Table 2. Project deliverables with due dates and formats, aligned with EMC's goals for translation and transparency of research results.

These deliverables ensure open-access, traceability, and usefulness of findings across all project phases, from stakeholder engagement to regulatory guidance.

Research Methods

This study will deploy a multi-phase, data-driven approach to evaluate the effectiveness of fuel hazard reduction treatments authorized under 14 CCR § 1051. The research will integrate spatial data collection, remote sensing analysis, physics-based fire behavior modeling, and decision-support tool development to deliver actionable information for landowners, registered professional foresters, and regulators.

The first component involves assembling a robust, spatially resolved GIS layer stack (Table 3), which will serve as the foundation for identifying eligible § 1051 parcels and stratifying them by forest type, ownership, and treatment history (see Tables A2, A3). This stack will be built in QGIS and structured into core thematic categories, including Base Layers, Forest Practice & Fuels Layers, Ownership & Land Use Layers, and Fire & Risk Layers. These will be described in detail in the subsection below. This spatial structure is critical for site selection, eligibility screening, and filtering by land type (e.g., private TPZ, non-industrial timberlands, conservation trust holdings).

Next, we will overlay and analyze a suite of remote sensing datasets, including NDVI (vegetation greenness), SAR (synthetic aperture radar for canopy moisture and structure), and, where available, LiDAR to evaluate canopy conditions before and after treatment. These datasets will support model representativeness, monitor vegetation recovery, and supplement stratification of treatment types.

The heart of the modeling work will be conducted using QUIC-Fire, a high-resolution, physics-based fire behavior model. This tool will simulate wildfire behavior under historical and planned § 1051 treatment configurations, allowing the project to quantify changes in fire intensity, spread rate, and crown fire activity. A more detailed modeling methodology is outlined in the section that follows.

To ensure these results translate into practical tools for practitioners and policy stakeholders, the project will culminate in the development of a decision-support framework. This framework will take the form of a practitioner-ready PDF document that synthesizes spatial data, QUIC-Fire outcomes, and regulatory guidance for applying § 1051 effectively. It will be designed to help users identify when and where treatments are most effective and to support regulatory compliance. The PDF guidance will be complemented by a downloadable SQLite database of treatment outcomes, enabling users to explore site-level results interactively and integrate findings into their own planning workflows.

Data Sources and Validation Plan

This project will pull together more than a dozen GIS layers and data sources to achieve the goal of quantifying the effectiveness of the real-world implementation history of FPR § 1051 treatments in California (see Table 3 below). These data span jurisdictional layers, to fuel hazard treatment history layers, and fire perimeter monitoring layers. This comprehensive selection of data provides a means for locating the parcels that can serve as test cases for (QUIC-Fire) model validation, pre- / post- § 1051 treatment quantification, and fuels-based fire risk potential.

Layer	Source	Purpose	Link/Notes
		Base Layers	
CA State Boundary	US Census / CADWR	Map frame, clipping extent	gis.data.ca.gov/datasets/
County Boundaries	US Census TIGER	Zoning interpretation	census.gov/geographies/mapping-files/time-series/geo/
		Forest Practice & Fuels	
FRAP Fuel Hazard Reduction THPs (1051s)	CAL FIRE	Shows completed/planned THPs under §1051	calfire-forestry.maps.arcgis.com/home/item.html
CalTREES Treatment Metadata	CAL FIRE	Lookup THP attributes	caltreesplans.resources.ca.gov/caltrees/
LANDFIRE Fuel Loading Models (FLMs)	USGS / LANDFIRE	Model base inputs to QUIC-Fire	landfire.gov/fueldata.php
LANDFIRE Existing Vegetation Type (EVT)	USGS / LANDFIRE	Define forest types by treatment region	landfire.gov/viewer/
LiDAR Canopy Structure (if available)	OpenTopography	Validate post-treatment conditions	opentopography.org/
		Ownership & Land Use	
California Parcel Ownership (CPAD / private lands)	CPAD	Filter by land trust / private forest	calands.org/

Layer	Source	Purpose	Link/Notes
TPZ Zoning (Timber Production Zone)	County / CAL FIRE	Identify TPZ-compliant lands	County GIS portals or FRAP viewer
Federal and State Ownership (PAD-US)	USGS GAP	Mask out ineligible federal lands	usgs.gov/programs/gap-analysis-project/protected-areas
		Fire & Risk	
Fire Perimeters (Cal Fire / FRAP)	CAL FIRE	Validation of post-treatment fire	frap.fire.ca.gov/frap-projects/fire-perimeters/
Fire Hazard Severity Zones (FHSZ)	CAL FIRE	Contextualize treatment priority	osfm.fire.ca.gov/divisions/wildfire-planning-engineering/
WUI Boundary Layer	FRAP / CAL FIRE	Evaluate exposure in urban-edge zones	frap.fire.ca.gov/frap-projects/wildland-urban-interface-wui/

Table 3. GIS layer stack.

FRAP & CalTREES for identifying FPR § 1051 land

Identification of treatment areas governed by Forest Practice Rule § 1051 will rely on two authoritative and publicly accessible datasets: the CAL FIRE Fuel Reduction Projects v2 layer hosted by FRAP and the CalTREES Timber Harvest Plan (THP) database.

The **CAL FIRE Fuel Reduction Projects v2** dataset, published by the Fire and Resource Assessment Program (FRAP), provides spatially explicit polygons representing fuel reduction projects across California. Each polygon includes attributes identifying the treatment type, legal basis (e.g., § 1051), operational status (e.g., Approved or Completed), and treatment methods. This dataset will be used to:

- Delineate candidate parcels where § 1051-compliant fuel hazard reduction projects have already occurred.
- Support stratification by treatment status (e.g., historical vs. planned).
- Anchor QUIC-Fire simulations to verified spatial footprints.

The CalTREES THP Portal provides detailed plan-level metadata, including plan number, landowner/RPF contact, silvicultural system, treatment narrative, and timelines. This portal will be used to:

- Cross-reference and verify FRAP polygons by plan ID (PLAN_NUM or THP_ID).
- Extract textual descriptions and treatment intent for scenario modeling inputs.
- Support validation of treatment compliance with § 1051 restrictions (e.g., selective thinning, no even-aged management).

Together, FRAP provides the spatial anchor and CalTREES provides the regulatory and operational detail, enabling a robust, layered approach to identifying, verifying, and modeling § 1051 lands statewide.

Use of LANDFIRE Data to Drive QUIC-Fire Simulations

LANDFIRE datasets will provide baseline fuel structure and vegetation inputs for QUIC-Fire simulations, including Fuel Loading Models (FLMs), Existing Vegetation Type (EVT), and Canopy Base Height and Canopy Bulk Density layers. These inputs will define the pre-treatment condition for § 1051 parcels and support parameterization of fire behavior across varied forest types. LANDFIRE data will be clipped and aligned to treatment polygons and, where available, enhanced with LiDAR and NDVI-derived structural updates to reflect post-treatment conditions. This approach ensures consistent, spatially comprehensive fuel data for statewide modeling.

LiDAR (Where Available) for Pre/Post-Treatment Fuels Characterization

LiDAR data will be incorporated where available to enhance the accuracy of fuel structure inputs used in modeling fire behavior. Specifically, LiDAR provides **three-dimensional information** on **canopy height, understory density, and vertical fuel continuity**, all of which are critical for evaluating the effectiveness of § 1051 treatments aimed at reducing ladder fuels and crown fire potential.

This dataset will serve three key purposes in the analysis:

1. **Baseline Fuels Structure**: Where pre-treatment LiDAR is available, it will be used to characterize canopy and understory structure prior to the implementation of thinning or fuel reduction treatments.
2. **Post-Treatment Structure**: Post-treatment LiDAR (where available) will allow us to **quantify structural changes** resulting from § 1051 treatments, such as increased tree spacing, raised crown base heights, and reduced vertical fuel continuity. These observed structural outcomes will be used to construct **more accurate post-treatment input layers** for QUIC-Fire simulations.
3. **Post-Fire Validation of QUIC-Fire Accuracy**: Where available, simulated outcomes in stand structure will be compared to LiDAR measured changes in structure.

LiDAR data will ensure calibration of QUIC-Fire simulations so that they better represent real-world wildfire outcomes. This enables a more meaningful interpretation of differences in simulated fire behavior under treated vs. untreated scenarios, and thus a better assessment of the efficacy of § 1051 treatments.

LiDAR coverage in California is patchy and varies widely by county and agency initiative. We will explore available datasets from the following sources:

- **OpenTopography** (https://opentopography.org/) - a leading repository for open-access LiDAR.
- **USGS 3DEP** (https://www.usgs.gov/3d-elevation-program) - for national LiDAR availability.
- **County GIS Portals** - for parcel-level LiDAR in areas such as Sonoma, Marin, and Humboldt Counties.
- **CAL FIRE/FRAP** internal datasets.

Because LiDAR data acquisition is costly and not statewide, we anticipate using it in **case study regions** where pre- and post-treatment as well as post-wildfire datasets exist and are spatially coincident with § 1051 treatment polygons. These regions will serve as high-confidence validation zones to anchor broader interpretations. Where LiDAR data is unavailable, we will use surrogate data layers including **LANDFIRE Fuel Loading Models (FLMs)**, **SAR and NDVI time series**, and **treatment metadata** to estimate structural changes.

Sentinel-1 SAR and Sentinel-2 NDVI for Fuels Characterization (Primary Where LiDAR is Unavailable)

Where LiDAR is not available, **Sentinel-1 Synthetic Aperture Radar (SAR)** and **Sentinel-2 NDVI** will serve as primary remote sensing tools for pre- and post-treatment fuels characterization. These sensors offer statewide coverage, frequent revisit times, and data continuity essential for broad spatial analysis of § 1051 treatment outcomes.

Sentinel-1 SAR operates in the **L-band** microwave spectrum, which **is particularly sensitive to woody biomass and canopy structure.** At its spatial resolution (~10–20 m), L-band SAR is effective for detecting changes in **stand basal area, canopy closure, and general structural density**. While it cannot reliably distinguish fine fuels such as litter or small limbs, it is well suited for detecting stand-level thinning associated with § 1051 treatments. This makes it valuable for identifying areas where selective removal of ladder fuels has occurred and monitoring their structural recovery over time.

Sentinel-2 NDVI, a vegetation density index, will be used to assess **canopy cover dynamics** across multiple years. Following § 1051 treatment, where subdominant and understory trees are thinned while dominant trees are retained, NDVI patterns should show a **modest decline immediately** after treatment, followed by a **predictable, gradual recovery** over 2–5 years (which is particularly apparent in shoulder-season dynamics). This behavior will help identify **prototypical treatment sites** and support the stratification of simulation ensembles in QUIC-Fire.

Together, SAR and NDVI will form the backbone of our statewide fuels structure analysis where high-resolution LiDAR is unavailable, enabling comprehensive treatment characterization and improving the accuracy of both pre-treatment simulation inputs and post-treatment fuel hazard reduction validation.

Scientific Uncertainty

This project directly addresses multiple sources of scientific uncertainty identified in Section 3.1 of the EMC's Strategic Plan, particularly the effectiveness of treatment types across varying forest structures, seral stages, and fire regimes. It also addresses uncertainty around vegetation recovery rates and their influence on long-term fire hazard, which is currently under-monitored.

Uncertainty in remote sensing classifications, treatment records, and simulation inputs (e.g., fuel structure and weather) will be mitigated through the use of well-established datasets (e.g., CalFIRE FRAP, CalTREES, Sentinel), multi-year temporal composites, and ensemble modeling with QUIC-Fire under standardized conditions.

Geographic Application

This project will produce findings with **Statewide applicability**, grounded in the analysis of real § 1051 treatment sites across diverse land ownerships and ecological regions. While not all § 1051 parcels will be modeled, this study will focus on **representative cases selected to reflect the range of land-use types and forest conditions** where § 1051 treatments are implemented (see Table A1).

Using the GIS layer stack detailed in Table 3, we will assess the distribution of § 1051-eligible parcels by land-use type (e.g., TPZ, private non-industrial, trust-managed lands) to ensure the selected study sites are stratified by both treatment type and landscape context. This enables generalizable insights that can be extrapolated across similar land types throughout the state.

By filling critical data gaps identified in the EMC Strategic Plan and delivering spatially-aware decision tools, the project will support science-based planning and implementation of fuels treatments statewide.

Critical Question Theme and Forest Practice Rules or Regulations Addressed

This project addresses:

- **Theme 6 - Wildfire Hazard**, specifically:
    - **Critical Monitoring Question (c):** *Are the FPRs and associated regulations effective in managing fuel loads, vegetation patterns and fuel breaks for fire hazard reduction?*
- **Theme 12 - Resilience to Disturbance in a Changing Climate**, specifically:
    - **Critical Monitoring Question (a):** *Are the FPRs and associated regulations effective in improving overall forest wildfire resilience and the ability of forests to respond to climate change (e.g., drought, bark beetle), variability, and extreme weather events?*

Relevant Forest Practice Rules (FPRs):

- **14 CCR § 1051** - Fuel hazard reduction

Project Relevance:
This project is designed to directly evaluate the effectiveness of fuel hazard reduction projects conducted under 14 CCR § 1051, using post-treatment fire behavior modeling and vegetation structure analysis. By simulating fire behavior with QUIC-Fire under observed pre- and post-treatment conditions, and stratifying case studies by forest type and land use, the project will quantify how § 1051 treatments affect key metrics such as crown fire potential.

The integration of calibrated remote sensing data and publicly verified treatment records allows for objective, scalable assessments of treatment performance over time. This provides EMC and state agencies with a quantitative feedback loop to understand where FPR-aligned treatments are achieving the intended hazard reduction and where retreatments or alternative prescriptions may be warranted.

Through this focused assessment of § 1051 effectiveness, the project supports adaptive refinement of Forest Practice Rules and enhances the precision of treatment planning, improving both regulatory compliance and fuel management efficiency statewide.

Key Personnel, Collaborations and Project Feasibility

This project is a collaboration between **CARBON SOLUTIONS** and **UC San Diego / Los Alamos National Laboratory (LANL)**, combining the UCSD/LANL world-leading fire science and modeling capabilities—specifically **QUIC-Fire**, a model developed with California ecosystems in mind—with CARBON SOLUTIONS' strengths in remote sensing, data systems, and operational tool development (QUIC-Fire development was first funded by the CARBON SOLUTIONS CEO, Richard Middleton, while at LANL). This partnership ensures both scientific rigor and practical, scalable delivery, forming a proven team positioned to generate rapid, actionable results tailored to California's forest management needs.

- **Dr. Bjorn Brooks** (CARBON SOLUTIONS) will lead project management and the identification and stratification of FPR § 1051 parcels. Dr. Brooks has extensive experience in private and public research in this area, including six at the USDA Forest Service's Eastern Forest Environmental Threat Assessment Center, where he conducted research on landscape change and forest resilience under environmental stressors.
- **Dr. Rod Linn** (LANL/UCSD) will support QUIC-Fire simulations and guide integration of modeling outputs into the broader analysis. As the original developer of QUIC-Fire and a pioneer in physics-based wildfire modeling, Dr. Linn will ensure that simulation design aligns with real-world treatment dynamics and that input data is configured to accurately represent § 1051 fuel structures. He will also lead technical interpretation of fire behavior outputs in the context of treatment effectiveness. Dr. Linn's time is supported by aligned ongoing work with UCSD and LANL.
- **Dr. Amy Jordan** will design the QUIC-Fire modeling scenarios based on available § 1051 case studies and lead development of stratified simulation ensembles, as well as support QUIC-Fire simulations. She will also assist in stakeholder engagement and results interpretation. Dr. Jordan has served as Principal Investigator on two Department of Energy grants under the *LOCAETA* initiative, focused on air quality and emissions analysis.
- **Carl Talsma** will lead procurement and analysis of remote sensing data, including NDVI and SAR time series, to characterize structural change and support fuel input

development, as well as support QUIC-Fire simulations. Carl previously served as PI of a NOAA-funded research effort investigating methane emissions using multi-sensor satellite datasets.

- **Dr. Richard Middleton** will support project strategy and execution, drawing on his leadership experience at LANL and his role in originating and advancing the QUIC-Fire model. His technical oversight will ensure rigorous model implementation and stakeholder-aligned delivery.

CARBON SOLUTIONS brings proven execution and technical expertise: since its founding in 2021, the company has been competitively selected for over 100 funded projects totaling $19 million, with 70% of its portfolio supported by federal and state government, 20% by non-profits, and 10% by private industry. CARBON SOLUTIONS was founded by Dr. Middleton to advance scalable, science-based climate solutions.

Requested Funding

Total: $451,346.31
FY 1: $150,448.77 — Stakeholders & Data Acquisition
FY 2: $150,448.77 — Intensive Modeling
FY 3: $150,448.77 — Refinement & Engagement

The **Year 1** budget ($150,448.77) includes personnel costs (salaries and fringe for four research employees at CARBON SOLUTIONS and two support staff), indirect costs, and computing expenses. This phase covers stakeholder interviews, GIS layer acquisition, initial site selection, and forest stratification. It also includes **travel for 1-2 researchers to California** for a site visit and stakeholder meetings with **CAL FIRE foresters, Region 5 USDA Forest Service**, and demonstration forest staff (e.g., Jackson Demonstration State Forest or similar) **to better understand on-the-ground implementation of § 1051 treatments** and to compare with treatment data found in the FRAP database. The travel budget also supports Dr. Linn's participation.

The **Year 2** budget ($150,448.77) includes similar personnel and indirect costs, with expanded computing expenses, publication support, and **a second stakeholder engagement trip** to present preliminary results and receive mid-project feedback. This is the primary simulation phase, when QUIC-Fire models are run for each treatment regime across representative forest types, and early analysis is used to adjust methodology and outputs in response to stakeholder priorities. The travel budget also supports Dr. Linn's participation.

The **Year 3** budget ($150,448.77) covers continued personnel and overhead, advanced modeling refinement, and dissemination. It includes **a final in-person trip** to engage key decision-makers and practitioners for presenting actionable guidance and sharing the interactive map viewer and decision-support framework. The travel budget also supports Dr. Linn's participation.

Final deliverables will include an interactive § 1051 outcome and risk mapping tool, technical guidance documentation, a downloadable SQLite database of fire treatment outcomes, and one or more peer-reviewed publications or memos. The annual budget reflects the workload in simulation, stakeholder iteration, and end-user product delivery.

Appendix Items

Below is a table that illustrates several different land-use types that are subject to 14 CCR § 1051 and provides links to the GIS data sources we plan to use to facilitate spatial identification of eligible parcels. Small Private Parcels (<3 acres) and Federal Lands are not covered by 14 CCR § 1051.

Table A1. Table of GIS Layers & Data Sources for Land Types Relevant to 14 CCR § 1051

Land Type	GIS Layer or Data Source	Link / Notes
Private Timberlands (TPZ-zoned)	CalFire Timber Production Zone (TPZ) GIS	TPZ Layer on FRAP Viewer - May have to manually request shapefile.
Non-TPZ Private Forestlands	California Land Ownership (Parcel + Use)	CPAD + CAL FIRE Land Use Data - CPAD shows ownership; combine with zoning from county/city GIS or Forest Service data.
Industrial Timberlands	Timber Harvest Plans (THPs) under § 1051 (FRAP)	Fuel Hazard Reduction THPs (FRAP)
Tribal Forestlands	Tribal Lands (US Census / BIA)	US Census TIGER Tribal Lands Shapefile
Rangelands with Timber Component	USFS CalVeg / LANDFIRE EVT + Ownership Overlays	LANDFIRE EVT (Existing Vegetation Type) - Use CalVeg for finer resolution on rangeland/woodland overlaps.
Conservation Trust Forests	Protected Areas Database (PAD-US / CPAD)	CPAD / PAD-US - Filter for “private nonprofit” or “land trust” ownership and “conservation forest” designation.
State Forests	CAL FIRE Demonstration State Forest Boundaries (FRAP)	Jackson and Other State Forests (FRAP) - May be embedded in ownership layer.

Table A2. Which lands are subject to FPR 14 CCR § 1051?

14 CCR § 1051 primarily applies to non-federal, commercial timber-producing forestlands, including private TPZ parcels, industrial timber holdings, and conservation trust lands. These lands must submit a Modified Timber Harvest Plan (THP) for approval, and treatments must be designed to reduce fire hazard rather than maximize harvest volume.

Land Type	Description	Eligibility for § 1051	Notes
Private Timberlands (TPZ-zoned)	Privately owned lands zoned as Timber Production Zone (TPZ) under the California Timberland Productivity Act.	Eligible	Most common application; THP required for commercial harvest including fuel hazard reduction.
Non-TPZ Private Forestlands	Private forested lands not formally zoned as TPZ, but with merchantable timber and forest resources.	Eligible (if THP is filed and approved)	Must comply with additional CEQA provisions unless exemptions apply.
Industrial Timberlands	Large privately owned timberlands managed for commercial production (e.g., Sierra Pacific Industries).	Eligible	Frequently use § 1051 for strategic shaded fuel breaks and fire-resilient stand structure.
Tribal Forestlands	Forested lands owned or managed by California Native American tribes.	Partially eligible	Only if voluntarily entering into THP compliance or via cooperative agreements.

Rangelands with Timber Component	Mixed-use lands with grazing but some forest/timber cover, potentially eligible if THP is filed.	Conditionally eligible	Must meet timber stocking criteria to qualify under FPR definitions.
Conservation Trust Forests	Lands owned or managed by land trusts or NGOs (e.g., TNC, Save the Redwoods League).	Eligible (if THP submitted)	May use § 1051 for fuel reduction to protect ecological or community values.
Small Private Parcels (<3 acres)	Small holdings adjacent to WUI or forested areas, often not managed under THPs.	❌ Not eligible	These parcels typically fall under exemptions (e.g., § 1038), not § 1051.
Federal Lands (USFS, NPS, BLM)	Managed by federal agencies.	❌ Not eligible	Not subject to California Forest Practice Rules; managed under federal NEPA and internal guidelines.
State Forests (e.g., Jackson Demonstration State Forest)	Forests managed by CAL FIRE for research, demonstration, and commercial harvest.	Eligible	Often operate under long-term THPs, but can implement § 1051 projects for hazard reduction.

Table A3. Checklist table for 14 CCR § 1051-eligibility - 14 CCR § 1051 Key Requirements

Category	Requirement	Citation
Parcel Size Eligibility	Project area must be ≥ 5 acres and ≤ 2,500 acres.	§ 1051.1(a)(1), § 1051.2(a)
Land Ownership	Applies to nonfederal lands where landowners seek to reduce fuel hazards through limited timber operations.	§ 1051.1(a)
Harvest Objective	Harvest must be designed to reduce surface and ladder fuels, not regeneration-based (e.g., no even-aged or stand-replacing harvests).	§ 1051.3
Silvicultural System	Must use selective thinning (favoring retention of dominant/co-dominant trees), not regeneration methods.	§ 1051.3, § 1051.5
Cohort Retention	Dominant and co-dominant trees must be retained. Cutting of these cohorts is allowed only to meet spacing objectives to reduce crown fire risk.	§ 1051.5(b)(4)
Post-Harvest Stocking	Must meet minimum post-harvest stocking standards (as per 14 CCR § 913.3, § 933.3, or § 953.3 depending on region).	§ 1051.6
Fuel Treatment Intent	Must result in conditions that reduce fire intensity, rate of spread, and crown scorch or consumption.	§ 1051.3

Even-aged Management	Prohibited. The plan cannot use even-aged management as defined in the rules.	§ 1051.5(b)(1)
Vegetation Retention	Requires spatial distribution and retention of healthy, fire-resilient trees (usually large-diameter, widely spaced individuals).	§ 1051.3, § 1051.5
Slope Limitations	No operations on slopes >65% unless specific exceptions apply (e.g., stable ground and erosion controls).	§ 1051.5(b)(6)
Roads & Equipment Use	New road construction is restricted; low-impact equipment is encouraged to minimize soil disturbance.	§ 1051.5(b)(8)
Timeframe for Completion	Operations must begin within 3 years of plan approval and be completed within 5 years.	§ 1051.4