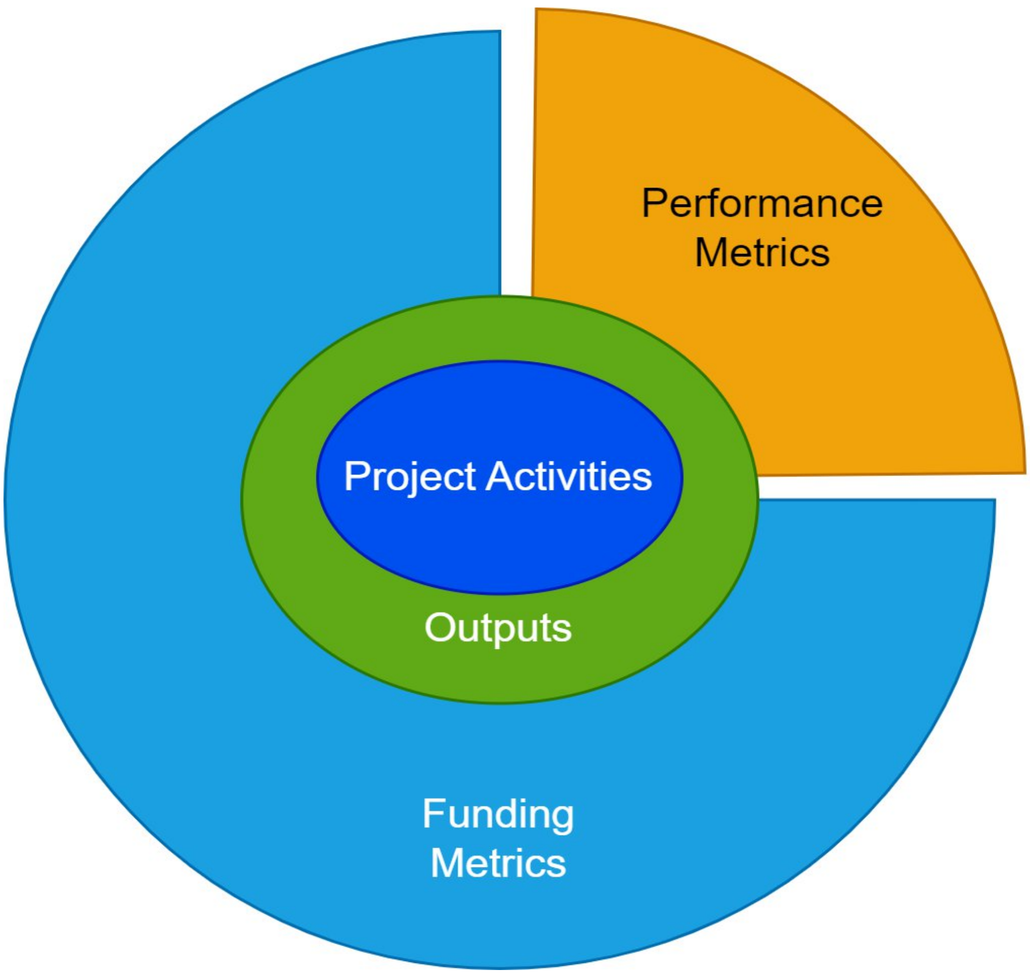
METRICS & INDICATORS PROPOSAL

Healthy Eldorado Landscape Partnership

Final Version May 2025



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Executive Summary

The Healthy Eldorado Landscape Partnership (HELP) endeavors to increase the funding volume and the pace and scale of project implementation across the Eldorado National Forest and down into watersheds flowing out of the forest. HELP is pursuing a data-driven approach implemented through a Watershed Outcomes Bank. The Bank approach helps to build up a larger pool of funding, identify and cultivate an inventory of high-priority and funding-/permit-ready projects, secure large-scale project financing, and ensure that project work aligns with and can be related back to regional scale objectives. HELP's Data Work Group evaluated 65 metrics tied to land use and conservation/restoration across the Sierra to Sea area of interest (AOI) covering watersheds of the South Fork American, Cosumnes, and North Fork Mokelumne Rivers. Of the 65, HELP's Data Group narrowed down to 18. The 18 metrics identified were divided into funding (indicators well-established with funders) and performance (longer-term landscape indicators) metrics. The next steps are testing the metrics to attract funders for projects in the AOI and evaluating the success of implemented projects in a cost-efficient and feasible manner for HELP project partners.

Background

The Healthy Eldorado Landscape Partnership (HELP) is intended to buttress the Eldorado National Forest Resilience Strategy while taking aim at the impediments standing in the way of landscape-scale conservation/restoration. In addition to trying to secure and leverage more funding resources, HELP endeavors to address constraints surrounding workforce attrition, sawmill and biomass utilization operational capacity, planning resources, and acquisition of the physical equipment to make the transformational changes needed to build an ecologically and economically resilient landscape through a sustainable proactive forest and watershed management. This Metrics Proposal document is focused in particular on building up a larger pool of funding, identifying and cultivating an inventory of high-priority and funding-ready projects, securing large-scale project financing, and ensuring that project work aligns with and can be related back to regional scale objectives.

Methodology

The HELP Data Workgroup worked through a large volume of data, models, tools, metrics, and frameworks to identify a select group of metrics that could link together watershed resilience objectives, projects, funder needs, and regional resilience outcomes into an actionable

Figure 1. Broad categories identified for metric development.

framework that would help us secure more funding and financing, cultivate better projects, and ensure ecological progress.

This exercise is essential because numerous generally aligned but specifically different funding and implementation efforts are underway across the region. The Workgroup's operating theory was that if we could identify a handful of "Rosetta Stone" metrics that could be applied to most project types, matter to most funders, and help determine the portfolio of projects that would maximize environmental outcomes[1] most cost-effectively, *then* we could better integrate otherwise fragmented efforts into a more powerful regional effort. The Workgroup understood that this process would not cover all projects, funders, or stakeholder needs but sought to maximize overlap to simplify the complexity currently associated with converting insight into action on the ground.

To do this, the HELP Data Work Group identified core land management activities relevant to the landscape (Figure 1). Then the Group undertook a comprehensive evaluation of quantification, planning, and progress indicator metrics that could be applied to each of those project types in the upper and lower portions of the Cosumnes watershed, and then selected the most effective metrics that could help link together project, funder, and landscape health scales (Figure 2).

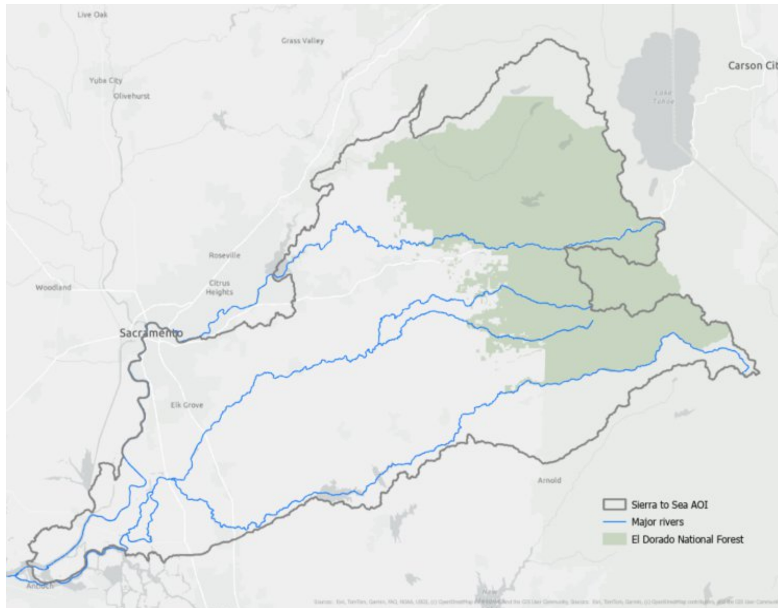
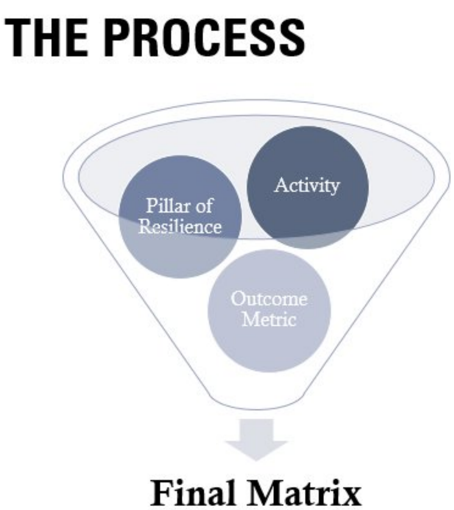


Figure 2. Area of interest for the metrics evaluation.



<u>Evaluation Criteria (0-5)</u>

1. Project → Landscape
2. Feasibility/Measurability
3. Beneficiary Interest
4. TCSI Pillars of Resilience Linkage
5. Representative of Practice/Treatment

65 Activity-Metrics Combinations screened

Figure 3. Process and evaluation criteria for screening metrics.

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[1] Outcomes (e.g., water volume increase) should be distinguished from outputs (e.g., acres treated), data layers, and goals (e.g., achieve forest resilience on a landscape by 2045).

The HELP Data Workgroup considered the following criteria when evaluating potential metrics (Figure 3):

- Outcomes gleaned by metrics are meaningful at both the project- and landscape-scale;
- Outcomes can be feasibly quantified/tracked at periodic intervals using well-established models and publicly available data;
- Outcomes are relevant to stakeholders, including key recurring funders; and
- Outcomes are representative of the Tahoe Central Sierra Initiative (TCSI) Pillars of Resilience objectives, and maximize overlap with the California Wildfire Taskforce core reporting metrics.

The results of this group effort were the selection and characterization of 17 specific metrics, which fall into two categories: 1) funding metrics; and 2) performance metrics and connected to water quantity, water quality, flood reduction, carbon sequestration, wildfire risk reduction, biomass removal, forest resilience, and biodiversity outcomes.

Metrics

The Data Work Group categorized the metric into funding and performance metrics. **Funding metrics** quantify the improved environmental uplift (or outcomes) generated from implementing one of 11 targeted conservation project/action types that are ecologically relevant in this geography. These metrics are being piloted in the Caldor-Cosumnes focus area.

The second set of **performance metrics** was selected by the HELP Data Group to help better identify priority areas for work, understand the current status of the landscape, and measure success of individual and collective projects. They were selected for the following reasons:

- Long-term landscape indicators
- Not attributable to a particular project
- May be composite indexes that are helpful for measuring overall outcomes, but may not be suitable for communicating benefits to beneficiaries and payors, or supporting project-scale prioritization
- Link to other data sources, planning efforts or tools, e.g., the Pillars of Resilience, Tahoe Central Sierra Initiative, Regional Resource Kits, PlanScape)
- Measure landscape-scale outcomes

The relationship between projects, outputs, funding and performance metrics are shown in Figure 4.

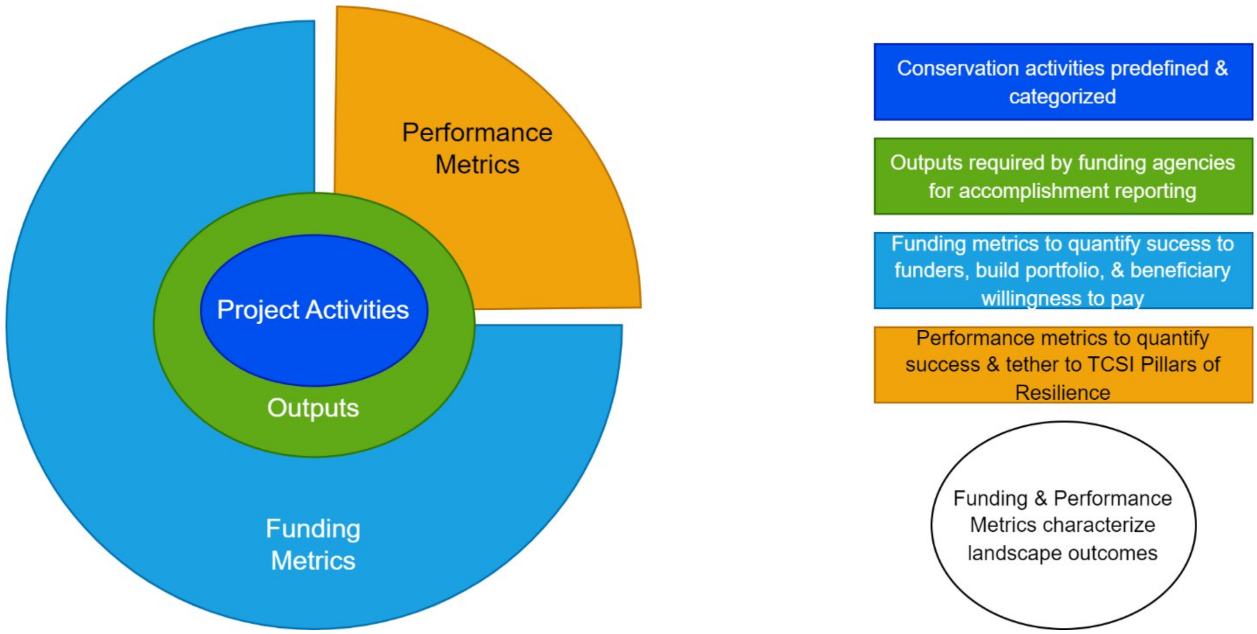

Figure 4. Relationship between project activities, outputs, funding and performance metrics.

Funding Metrics

Funding Metrics will be primarily used by partners to develop a watershed-scale project portfolio, build up a broader pool of funders/buyers, and demonstrate progress against regional resilience targets (Table 1). For the Caldor-Cosumnes Focal Area, in which we are piloting the application of these metrics through the Innovative Finance for National Forests grant and the resulting Watershed Outcomes Bank pilot, partners identified a refined list of prevalent project types (managed aquifer recharge, on-farm irrigation upgrades, habitat/flood land leasing, riparian restoration, pre-fire thinning, post-fire restoration, wetland restoration), and identified the metrics, models, and data to calculate water volume increases ($/Acre ft/yr), and reductions in sediment (USDA NTT, $/lb/acre), GHGs ($/CO2e/acre), flood risk reduction (% area risk reduction) and fire risk reduction (% area risk reduction, $/reduction in flame length/acre) of each.

These pieces come together in a Solver Tool built by The Freshwater Trust (TFT) and Radbridge Inc. (explanatory video). The Solver Tool includes watershed targets established by other regional plans and the above-described potential project activities and then identifies an optimal funding and implementation solution for achieving those multiple regional resilience targets. It does so by applying per-acre costs and the above benefits for each activity (e.g., $/acre ft/year of water volume increased), setting project supply constraints based on what is possible in the geography, and then “solving” for an investment portfolio that articulates the high-level pathway to most efficiently achieving all the watershed outcome targets.

The HELP Data-Subgroup and the Caldor-Cosumnes Subgroup are now using the Solver Tool results to help collate and identify a set of projects within the Caldor-Cosumnes watershed area. With that information, partners are now pursuing more coordinated funding and implementation efforts.

This is also an opportunity to test the efficacy of biophysical models and requisite data currently available under each Outcome category. If those models can generate defensible benefits estimates, metrics can be expanded to other HELP Focal Areas for similar portfolio development.

	FUNDING METRICS								PERFORMANCE METRICS											
ACTIVITIES																				
Thinning	X	X			X	X	X	X	X		X		X	X	X	X	X	X	X	X
Prescribed Fire	X	X			X		X		X		X		X	X		X	X	X	X	X
Meadow Integrity	X	X	X	X		X			X	X										
Irrigation Upgrades	X	X		X					X										X	
Riparian Restoration	X	X	X	X					X										X	
Crop Conversion	X	X		X					X											
MAR Activities	X	X	X	X					X	X										
Invasive Species/IPM	X					X										X			X	X
Reforestation		X		X					X			X				X	X	X	X	X
Postfire Restoration		X		X		X			X	X		X			X	X			X	X
Slope & Ground Stabilization		X		X					X			X							X	
OUTCOMES																				

Table 1. Outcome Metrics Cross-walked to activity types and connected to outcomes. Post fire restoration may include bank stabilization, meadow restoration, wetland enhancement, and shoreline protection. IPM = integrated pest management, ET = evapotranspiration, WUI = wildland urban interface, SDI = stand density index, FRID = fire return interval departure, TSLF = time since last fire, NDVI = normalized difference vegetation index, MAR = managed aquifer recharge.

Performance Metrics

Funding Metrics can be complemented by Performance Metrics to better tether specific anticipated benefits associated with delineated and defined project activities (Table 1). Together, funding metrics and planning/progress indicators provide a more holistic set of information to help identify and plan better projects, ensure more reinforcing benefits, track progress against regional objectives, and document project outcomes in units that can be tracked and evaluated against multiple grant or contract reporting requirements.

These indicators have the added benefit of a) better articulating how project-level investments are affecting landscape-scale outcomes (which is relevant to stakeholders such as the California Wildfire & Forest Resilience Task Force); and b) communicating to funders how their investments are generating real, measurable changes over time. As the TCSI Project Tracker gets underway, these outcomes can be embedded within the portal as a dashboard for assessing progress over time.

Details on each funding and performance metric can be found in Appendix 1.

Implementation

The funding and performance metrics are designed to be interdependent: the funding metrics are designed to secure as many project revenue streams as possible, whereas performance metrics aim to measure success. The Watershed Outcomes Bank designed to integrate funding metrics through the following steps (Figure 5):

1. **Targets and solutions**: Identify watershed-based resilience targets, quantify potential project outcomes in those metrics, and solve for the most cost-effective set of projects.
2. **Project supply**: Cultivate an inventory of funding-ready priority projects that align with the Solver Tool results.
3. **Funding pool**: Leverage, match, and aggregate otherwise isolated and timing-misaligned funding into a hub.
4. **Upfront financing**: Convert consolidated funding into working capital to accelerate project implementation.
5. **Simple project funding**: Make simple, compelling project funding offers that buffer partners from risks, complexities, and uncertainty.

6. **Quantify, track & adapt**: Quantify and monitor progress over time to adapt funding and implementation strategies.

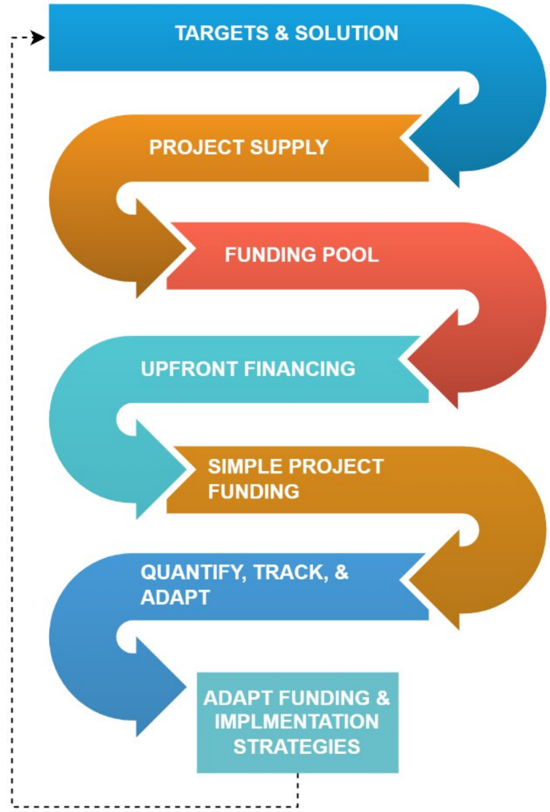

Figure 5. Watershed Outcomes Bank steps.

Solver Tool Constraints. Funding metrics will be utilized up front in the targets and solutions stage first to quantify potential project outcomes. By setting and refining constraints in the Solver Tool, partners will use the best available science to set/refine quantifiable regional resilience targets for each metric, confirm $/acre outcome assumptions for each action-metric combination, and determine roughly how much project supply there is for each action type in the region. The Work Group will assign Science leads to refine and vet the estimated benefits/acre numbers to each of the potential activity types using the Outcome-Action-Modeling approaches described below.

Optimal Project Portfolio. Based on these constraints, partners will identify an optimal project portfolio that will maximize multiple benefits in each watershed. The optimal solution can and should be weighted according to other variables, including timing to achieve desired results, realistic cost ceilings projected based on how much funding the implementing partners and the watershed can absorb each year and cumulatively, and project/permitting readiness.

Field-based Evaluation. Once actual activities are funded and completed, funding metric benefits will be measured to confirm alignment with modeled projections. Once verified, these benefits can be allocated to funders. A ledger will be developed and maintained by The Freshwater Trust to account for where the portfolio is producing tangible outcomes in the two watersheds.

Performance Metrics will be monitored every five years at the focal area scale and recorded in sub-regional reports. Results will be accounted for by running the Biophysical Models for the identified nine metrics associated with Outcome categories (Water Quantity, Carbon Reduced/Avoided, Wildfire Risk Reduction, Forest Resilience) on a periodic basis at the Focal Area level to capture progress towards landscape outcomes. In those instances, the assigned Project Lead will work with the Science Leads to ensure that projected benefits are modeled and incorporated into relevant funding applications (if appropriate) to bolster the proposals.

Governance & Workflow

Data is an integral part of the Watershed Outcomes Bank and provides the quantification of results, outcomes and benefits to attract funders and evaluate projects. The key roles and functions in the Watershed Outcome Bank are shown in Figure 6.

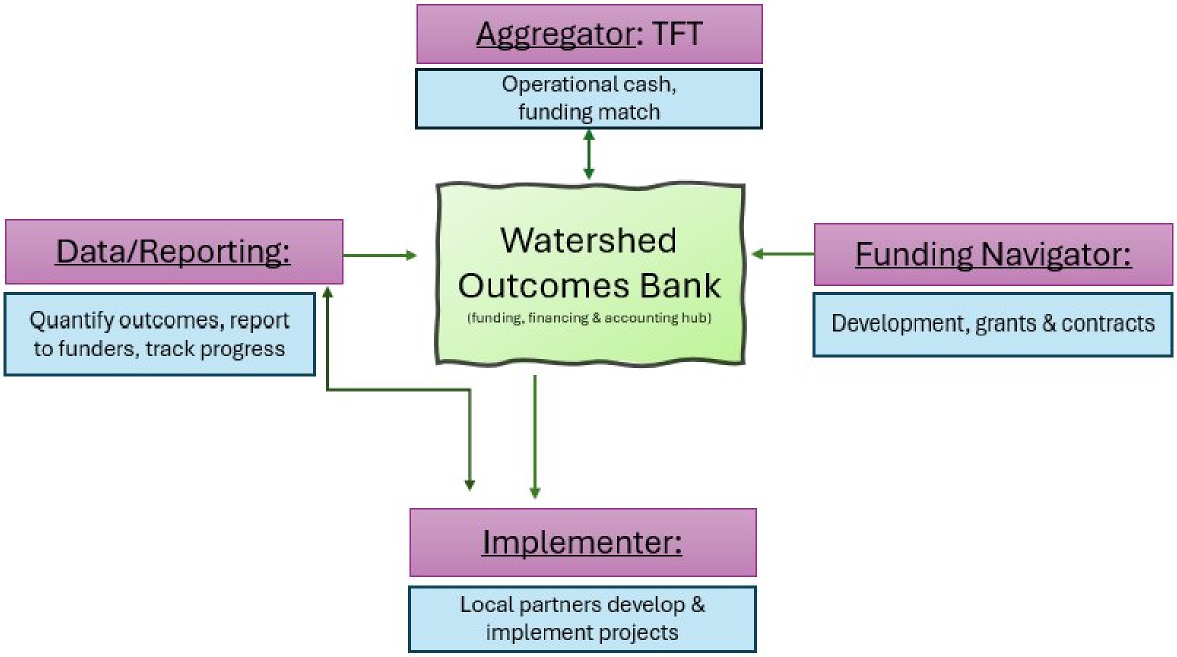

Figure 6. Watershed Outcomes Bank governance. The data/reporting will be led by each science lead.

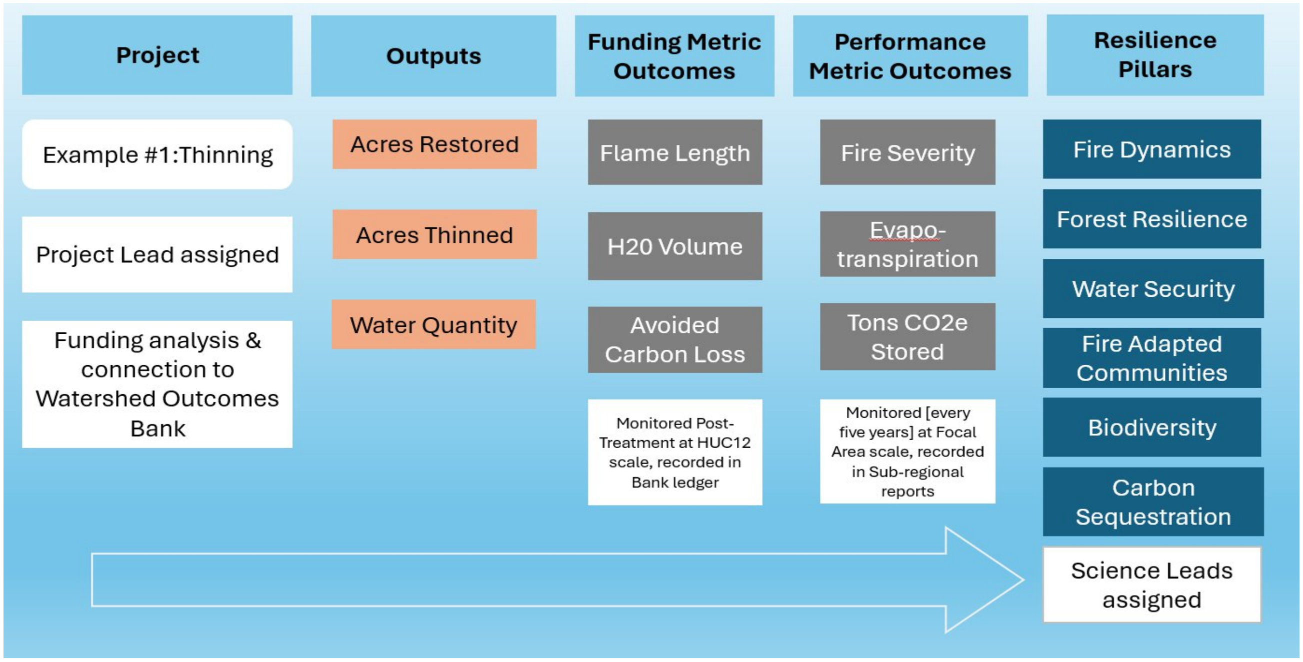

Figure 7. Example of Information workflow and governance. Funding metrics will be monitored post-treatment at HUC12 scale and recorded in the Watershed Outcome Bank ledger. Performance metrics will be monitored every 5 years at the focal area scale.

Science Leads will be appointed for each Outcome Category, irrespective of the type of metric. The Science Lead is responsible for working with Project Leads to complete and oversee biophysical modeling pre- and post- treatment, and aggregate activities at the appropriate watershed scales to record progress and trends (Figure 7). The Science Lead will also verify outcomes to report on the Watershed Outcomes Banking ledger once projects are completed. Project Outcomes recorded as Performance Metrics should be reported and tracked at the Focal Area scale on a more periodic basis and similarly communicated to TCSI, Forest Service, and Great Basin Institute Data leads.

Next Steps

As of May 2025, the HELP project partners will implement the following metrics proposal tasks:

1. Benefits mapping
2. Pilot and test metrics with funders and projects
3. Model performance metrics

APPENDIX 1: METRICS BY OUTCOME

Outcome: Water Quantity Increase

TCSI Resilience Pillar: Water Security; Wetland Integrity

1. Funding Metric: Change in Water Volume Available

Relevant Activities :

- Thinning and Harvesting
- Prescribed Fire
- Invasive Species/Integrated Pest Management
- Agricultural Water Use Efficiency
- Irrigation upgrades
- Managed Aquifer Recharge Activities

Biophysical Model and Data Requirements

- **Metric for thinning/prescribed fire/invasive species removal to reduce evapotranspiration**: The Center for Ecosystem Climate Solutions (CECS) uses the established relationship between Normalized Difference Vegetation Index (NDVI) and ET in the Sierra Nevada to estimate the impact of fuels reduction on water supply. The mean NDVI value for each pixel of the Landsat satellite image can be calculated for a full water year (October 1 - September 30) before fuel reduction activities begin. This NDVI value can then be used to estimate ET in millimeters and converted to acre-feet of ET for every pixel. To estimate expected change in annual ET resulting from a project, project treatments are cross-walked with different management scenarios preloaded in CECS with varying degrees of vegetation removal to produce estimated reduction in ET. For monitoring purposes, CECS data can be used to report ET reduction from updates in NDVI satellite data.
    - Geospatial scale: The CECS tool can be used at the project scale, but outcomes are intended to be averaged across the entire treatment polygon, and not interpreted pixel by pixel. CECS can evaluate different project footprints and compare the benefit estimates across specified CECS public lands treatment scenarios to obtain a range of values. Benefits, including water volume benefits (reduced ET), can then be calculated by finding the minimum and maximum values across different treatment scenarios and years of implementation. A sum total or percentage can be averaged across

all acres treated and a range of values reported. The data required for the runs includes: geospatial layers of the areas treated, the fraction (%) of original tree cover remaining, the fraction (%) of original shrub cover remaining, the fraction (%) of original detrital surface fuel remaining (100 hour and smaller + herbaceous), the fraction (%) of fuel bed depth change due to fuel rearrangement, and the fraction of the original aboveground live tree biomass remaining.

  - Frequency of updating: Annual
  - Science Lead: Blue Forest Conservation

- **Metric for agricultural water use efficiency**: The OpenET dataset has primarily been applied in California to serve as a compliance tool to determine water consumption for irrigated agriculture. It is currently being introduced as the primary tracking method for the Sacramento San Joaquin Delta under SB-88 (the state's water measurement and reporting measure, which requires most diverters to measure/model and report the amount of water they divert). OpenET is a suite of models that estimate the ET for a given crop on a specific field and would require the overlay of the ET of a new crop to determine the 'savings' resulting from a crop shift. OpenET data can be used in the lower portions of the watershed to analyze the change in ET demand for crops planted on a field.
  - Geospatial scale: OpenET is also at 30-meter resolution and covers the Central Valley including the American, Cosumnes, and Mokelumne River watersheds.
  - Frequency of updating: The OpenET datasets are typically refreshed daily or monthly depending on their original source. Blue Forest's model relies on frequently updated land imagery and public data sources. The timing of their update varies based on underlying data and their sources.
  - Science Lead: The Freshwater Trust

- **Metric for increases in groundwater infiltration:** Potential for groundwater increase have been preliminary modeled for the nearby adjacent Solano Subbasin. TFT previously applied a base multiplier of 1.2 AF/acre for suitable lands under the assumption that 2 AF of water would be delivered to the field. Potential for infiltration on fields would be based on the modified Soil Agricultural Groundwater Banking Index (SAGBI), as well as several physical/feasibility assumptions that dictate whether groundwater recharge is in fact suitable on a parcel
  - Geospatial scale: regional to parcel scale
  - Frequency of updating: whenever SAGBI layer updated, as needed programmatically
  - Science Lead: The Freshwater Trust

2. Performance Metric: Upland Change in Evapotranspiration Post-Thinning

Upland forest practices reduce overgrown forest cover to an ecologically appropriate level, resulting in reduced ET. The Blue Forest's Water Opportunities model calculates the change in ET (mm/year) following a reduction in basal area in the forest by up to 25%. This represents a rather conservative water opportunity function as treatments may be greater than 25% basal area removal but provides a baseline of project expectation in the upper watershed. The full methods of this model are detailed in Roche et. al (2020).

- Geospatial scale: Blue Forest's Water Opportunity model is 30-meter resolution and offers coverage across the entire upper watershed.
- Frequency of updating: Blue Forest's model relies on periodically updated land imagery and public data sources. The timing of their updates varies based on the underlying data and their sources.
- Science Lead: Blue Forest

3. Performance Metric: Normalized Difference Vegetation Index (NDVI)

Studies of groundwater dependent ecosystems that use remote sensing are based on the principle that groundwater dependent ecosystems maintain more consistent greenness on intra- and inter-annual timescales than surrounding ecosystems, due to their steady access to water supply (Dresel et al., 2010, Gou et al., 2015, Jin et al., 2011, Klausmeyer et al., 2019, Lv et al., 2013, Tweed et al., 2007). The green islands of groundwater dependent ecosystems can be identified by comparing remotely sensed data across times of contrasting water supply, or across landscapes. NDVI, essentially a measure of greenness, is based on a ratio of near infrared and red wavelengths and is primarily sensitive to chlorophyll. Researchers have used K-means clustering of standard deviation of NDVI over a year, NDVI in a dry year, and inter-annual standard deviation of NDVI to determine likelihood of pixels being groundwater dependent ecosystems (Gou et al., 2015). This method allows for the measurement of year over year change in groundwater-dependent ecosystem area. Data required for this analysis includes Planet Data which is privately aggregated data, additional data sources such as local vegetation classes and groundwater flow can assist in the remote sensing of ecosystem health.

- Geospatial Scale**:** Planet Labs offers the data used for this analysis at 1-3 meter resolution. This high-resolution data helps to overcome the mixed pixel problem when monitoring the recovery of small individual groundwater-dependent ecosystems within the program area. In addition, the newest generations of Planet sensors are available in 4-8 radiometrically consistent bands, allowing for the calculation of band indices that are common in remote sensing studies based on other satellite sensors.
- Frequency of Updating**:** Revisit times of Planet labs imagery is 24-48 hours resulting in close to real time data for analysis.

- Science Lead: The Freshwater Trust

Outcome: Water Quality Improved

TSCI Resilience Pillar: Water Security, Wetland Integrity

4. Funding Metric: Metric Tons of Sediment Removed or Avoided

Relevant Activities:

- Thinning
- Prescribed Fire
- Meadow Restoration
- Irrigation Upgrades
- Riparian Restoration
- Agricultural Water Use Efficiency
- Managed Aquifer Recharge Activities
- Invasive Species/Integrated Pest Management
- Reforestation
- Postfire Restoration (Streambank Stabilization)
- Other Slope & Ground Stabilization

Biophysical Model and Data Requirements:

- **Lower Watershed Projects (primarily on agricultural land):** The USDA Nutrient Tracking Tool (NTT) was developed to track the changes in sediment and nutrient load transport into waterways following the implementation of conservation activities on farmlands. This work has been extended to include near-stream conservation practices including increasing forest buffers and implementing streamside restoration projects which would be applicable to upper watershed activities. These benefits are correlated to the implementation of NRCS Conservation Practices as defined by their specifications. TFT runs this model at the field scale using the following data sets: Crop type (USDA-NASS Cropland Data Layer (CDL)), irrigation type–if applicable (predicted using machine learning unless a local data source has been identified with this information), soil type (USDA SSURGO), Field slope (USGS digital elevation model), field boundaries (delineated through machine learning technologies).

- Geospatial Scale**:** The scale of this model can be applied to the field level, the application of this across the landscape does require the use of machine learning to delineate the field boundaries and determine irrigation type. Once they are delineated this information is QA/QC'd to ensure accuracy to the field level.
- Frequency of Updating**:** USDA SSURGO datasets are updated annually. USDA NASS CDL datasets are updated annually. Field slope data from a USGS DEM model is typically derived from USGS topo maps which are updated on a three-year cycle, if the DEM utilized LiDAR this update may be more frequent.
- Science Lead**:** Blue Forest

- **Upper Watershed Pre-Fire Projects**: CECS uses the Revised Universal Soil Loss Equation (RUSLE), which calculates the long-term average annual soil loss from each point on the landscape. In CECS, this equation is solved twice, once for current vegetation conditions and again for bare ground; the difference between these two scenarios is the maximum impact that a disturbance could have on sediment erosion. To estimate the actual impact, this difference is then linearly scaled down based on the modeled flame length for the location. Inputs to RUSLE include climatic erosivity, soil erodibility, slope steepness, slope length, canopy cover, and a conservation practices factor. The CECS approach assumes that flame length is an appropriate proxy for changes to the ecosystem from a fire that would impact soil erosion, such as vegetation loss and changes in soil conditions. It further assumes that maximum flame length would result in the most extreme conditions (bare ground) and that the relationship between flame length and soil erosion is linear. Because RUSLE does not measure sediment transport, model outputs will likely be higher than actual sediment inputs to nearby waterways.
    - Geospatial scale: The CECS tool can be used at the project scale, but outcomes are intended to be averaged across the entire treatment polygon, and not interpreted pixel by pixel.
    - Frequency of updating: Annual
    - Science Lead**:** Blue Forest

- **Upper Watershed Post-Fire Projects:** awaiting data from https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1064286
    - Geospatial scale: 30m

- Frequency of updating: annually
- Science Leads**:** Blue Forest

Outcome: Flood Risk Reduction

TCSI Resilience Pillars: Water Security; Wetland Integrity; Social & Cultural Well-Being

5. Funding Metric: Reduced % Flood Celerity

Quantified in cost savings delivered to critical inundation zones

Relevant Activities:

- Meadow Restoration
- Riparian Restoration
- Managed Aquifer Recharge Activities (wintertime diversion of peak river flows onto river-adjacent land; water percolates on the ground to replenish shallow groundwater aquifer)

Biophysical Model and Data Requirements (not specific to individual project types; projects are inputs to this relational model): Unlike other outcomes described in this memo, quantifying flood risk reduction is inter-relational and occurs at the watershed scale. This is a three-step process. First, TFT's Science and Analytics team has developed a Muskingum flow routing model for the Cosumnes River. The purpose of the flow routing model is to predict discharge at any time and geographic point in the main stem of the river, given hydrographs of discharge in the primary tributaries (i.e., the North, Middle and South Forks). The model functions as a tool to forecast how altered flow regimes in the headwater catchments of the river—for example, increased streamflow attributable to forestry projects—could impact flow in the lower portions of the watershed.

Expected input data includes readily available NHDPlus stream networks and gaging station discharge time series for upstream boundaries and mid-stream locations and discharge and stage at downstream flood-risk locations of interest (e.g., USGS gage data). Additional data that may be used includes the National Water Model stream flow estimates. More intensive approaches than the Muskingum approach would include land surface modeling to route precipitation and runoff into the stream network coupled with a flood wave propagation approach (e.g., HEC-HMS style model). The model of the Cosumnes River was constructed to treat historical flows in the North and Middle Forks as upper boundary conditions. It is valid along the main stem as far downstream as the junction with Deer Creek, and it could be extended further downstream given additional discharge data from that tributary. As part of model development, historical flows were estimated in the ungauged South Fork, a tributary which contributes about 20% of the discharge at Michigan Bar.

The second step is to identify high risk flood areas in the watershed. This requires flood inundation mapping (FIM). There are several modeling tools that have been developed for FIM, all of which are generally related or similar to the Height Above Nearest Drainage (HAND) method (Aristizabel et al. 2023; Garousi-Nejad et al. 2019; Thalakkottukara et al. 2024). FIM methods are generally based on a digital elevation model (DEM) that indicates the difference in the elevation of a given point in the catchment area and the elevation of the stream channel to which the point drains following the flow direction. In the simplest form, a FIM method requires (1) developing a hydrologically corrected DEM and (2) creating synthetic rating curves for the downstream flood-risk locations of concern. An example of a FIM tool is the QGIS Floodplain Inundation Calculator (FIC).

Once the flood routing method has been calibrated to simulate baseline conditions, the effect of implementing upstream projects can be evaluated by modifying the celerity of the stream reaches at project locations within the model. The reduction in celerity due to a restoration project can be based on expert opinion, previous projects, or previous advanced hydrodynamic modeling examples of similar projects. Cost-benefit analyses of combinations of projects that provide the most cost-effective solutions to reduce flood risk can be identified through iterative model evaluations.

- Geospatial Scale**:** project scale or watershed scale.
- Frequency of Updating**:** input data sources are readily available and frequently updated. Only makes sense to update the inter-rational model as new slates of potential projects are developed.
- Science Lead**:** The Freshwater Trust

Outcome: Carbon Sequestered or Stored or Avoided

TCSI Resilience Pillar: Carbon Sequestration

6. Funding Metric: Reduction in CO_2e Emissions (Tons) from Integrated Forest Management

Relevant Watershed Activities:

- Thinning
- Prescribed fire

Biophysical Model and Data Requirements: Following are descriptions for "projected impact" quantification approaches (e.g., modeled outcomes based on a baseline v. treatment scenario), and "monitored/measured impacts" (observed carbon changes through remote sensing and/or field measurements).

- **Projected carbon (CARB)** from these activities can be calculated using the Climate Action Reserve's Reduced Emissions from Megafires Forecast Methodology. The REM protocol, however, uses FVS data to estimate forest growth and wildfire emissions. FVS, however, has limitations such as outdated allometric equations, it does not model fire or climate, and it underestimates cumulative fire impacts by treating emissions as point in time events. These methods estimate emissions, not changes in carbon stocks, the latter being more accurate. The CAR REM methodology has not generated credits due to these limitations.
- **Projected carbon** alternative can be found in Elias et al. (2025). Unlike FVS projections, the dynamic performance benchmark framework employed in this method better accounts for cumulative fire probability over time. This proposed methodology has not yet been adopted by state or federal agencies.
- The most accurate **monitored carbon** methods are currently under per review and will inform Verra's forthcoming Methodology for Avoided Forest Conversion from Decreased Wildfire expected mid-2025. These methods will offer the best available tools for tracking treatment impacts on carbon stocks over time (as opposed to estimating changes in emissions, two sides of the same coin) using annually updating dynamic baselines.
    - Geospatial Scale: Eldorado National Forest
    - Frequency of Reporting**:** annual
    - Science Lead: Blue Forest

7. Funding Metric: Additional CO_2 Equivalent (Tons) Stored from Reforestation

Relevant Watershed Activities:

- Reforestation
- Riparian Restoration

Biophysical Model & Data Requirements: Following are descriptions for projected impact quantification approaches, and monitored/measured impacts.

- **Projected carbon** can be estimates using CECs and the Verra VM0047 reforestation methodology. The Verra methodology is recognized as the most robust reforestation methodology on the carbon market.

- **Monitored carbon** can be measured using remote sensing and field plots to measure carbon gains. Methods are described in the Verra VM0047 methodology.
  - Geospatial Scale: Estimations of emissions reduced and carbon sequestered under this tool are based on a multi-county scale to localize the benefits of conservation practices better. The forest carbon metrics are 300m rasters. The belowground carbon dataset is 306 m/px. The World Conservation Monitoring Center has a belowground biomass carbon and soil organic carbon to 1m depth measured in tonnes/ha (WCMC, 2010). The WCMC dataset appears similar to the NASA data but seems to pick up more nuance in different values over the landscape
  - Frequency of Reporting: annual
  - **Science Lead:** American Forests

8. Funding Metric: Reduction in CO_2e Emissions (Tons) from Improved Land Management Practices in the Lower Watershed

Relevant Watershed Activities:

- Agricultural Water Use Efficiency
- Riparian Restoration
- Invasive Species/Integrated Pest Management

Biophysical Model & Data Requirements: Following is a description of a "projected impact" quantification approach for land improvement activities, primarily in the lower watershed.

- **Projected carbon**: The USDA Nutrient Tracking Tool (NTT) and USDA Carbon Capture (COMET-Planner) tools can account for carbon sequestration and GHG reduction from on-farm conservation projects. The COMET Planner is an interactive web tool designed to help implementers quantify the amount of greenhouse gas emissions reduced and the volume of carbon sequestered after the completion of specific conservation practices. Required information to use the COMET-Planner is the conservation practice and the acreage it will be implemented across. The web tool version of this model is currently publicly available but further investment would be required to make API calls to implement the model into TFT's current analytical portfolio. NTT, which TFT implements as part of their analytical toolset, is coupled to the CENTURY model. NTT provides highly synthesized outputs from the CENTURY model including annual carbon sequestration, expressed in terms of either carbon or CO_2-equivalent, and climate impacts which is a combination of CO_2 and N_2O emissions expressed in terms of CO_2-equivalent. TFT runs this model at the field or project scale using the following inputs: Crop type (USDA-NASS Cropland Data Layer (CDL), irrigation type (predicted using machine learning unless a local data source has been identified with this information), soil type (USDA SSURGO), Field slope (USGS digital elevation model), field boundaries (delineated through machine learning analyses).

- Geospatial Scale: usually for an individual practice on a parcel
- Frequency of Reporting: NTT (Tarleton State University) and COMET (Colorado State University) updated on regular cycles. Can update parcel-level conditions as often as desired
- Science Leads**:** The Freshwater Trust

9. Funding Metric: BDT biomass utilized

Relevant Activities:

- Thinning

Biophysical Model & Data Requirements:

Biomass utilized is arguably the most straightforward way to monetize forest carbon. USFS policy allows for biomass utilization to generate carbon credits and state agencies, such as CAL FIRE, are tracking bone dry tons (bdt) of biomass utilized for Forest Health and Business and Workforce Development programs. Biomass utilization credits rely on projects with monitoring components focused on permanence, rather than measuring annual changes in stock.

Three examples of biomass utilization with protocols include the following:

1. **Biochar.** The Climate Action Reserve Biochar Protocol is built with fire-adapted forests in mind and can be reported as tons of biochar or tons of CO_2e benefit.
2. **Biomass burial.** The Isometric protocol appears to be best suited for public lands in the US. Puro also offers a burial protocol. Biomass burial offers four times the sequestration potential of biochar but is limited to suitable disposal sites unlikely to be located on public lands. Burial can be quantified using simple multipliers.
3. **Soil amendments.** Chipping biomass and spreading on soil with composting tea may be another biomass utilization option. Protocol?
4. **Mass timber.** For small diameter wood that has not been chipped, mass timber may offer both biomass utilization and new wood product marketing at the same time, if a processing facility is close enough to where the biomass is produced.

- Geospatial Scale: project and stand level accounting
- Frequency of Reporting: Annual (according to the Task Force)
- Science Lead: CALFIRE

Outcome: Wildfire Risk Reduction

TCSI Resilience Pillars: Fire Dynamics, Fire Adapted Communities

10. Performance Metric: WUI Damage Potential

Relevant Watershed Activities:

- Thinning
- Prescribed Fire
- Invasive Species/Integrated Pest Management

Biophysical Model and Data Requirements: The Damage Potential in the WUI metrics combines the WUI data layer (defined by Calson et al. 2022) and the composite layer Damage Potential, developed by Pyrologix. Damage potential represents a relative measure of wildfire's potential to damage a home or other structure if one were present at a given pixel, and if a wildfire were to occur (conditional exposure). This index does not incorporate a measure of annual wildfire likelihood. Damage Potential is calculated using conditional risk to potential structures and conditional ember load index.

- o Geospatial Scale: 30 m raster
- o Frequency of Reporting: Annual (according to the Task Force)
- o Science Lead: Hugh Safford Lab, UC Davis

11. Performance Metric: Probability of High Severity Fire

Relevant Watershed Activities:

- Thinning
- Prescribed Fire
- Invasive Species/Integrated Pest Management

Biophysical Model and Data Requirements: Operational-control probability rasters indicate the probability that the head fire flame length in each pixel will exceed a defined threshold for certain types of operational controls, manual and mechanical. High severity fire represents fire with flame lengths exceeding 8 feet and are generally considered beyond mechanical control thresholds.

Creation of this metric followed the framework outlined in Scott and Thompson (2013). Pyrologix used the Wildfire Exposure Simulation Tool, a deterministic wildfire modeling tool that integrates variable weather input variables and weights them based on how they will likely be realized on the landscape.

- o Geospatial Scale: 30m Rasters
- o Frequency of Updating: Annually to every 5 years
- o Science Lead: Hugh Safford Lab, UC Davis

12.Funding Metric: % Change in Flame Length

Relevant Watershed Activities:

- Thinning
- Prescribed Fire
- Invasive Species/Integrated Pest Management

Biophysical Model and Data Requirements: CECS assumes standard fire weather conditions when modeling flame length and only accounts for ground-based fuels (shrubs and dead surface fuels) rather than tree canopy fuels. This conservative approach is intended to limit benefit estimates to a narrow and high-certainty range. To model flame length, CECS uses the Rothermel Fire Spread model, a method developed in the 1970s that forms the basis for all modern fire simulation models, including FSim, and is widely regarded to have a high level of rigor. The Rothermel model first calculates fire spread rate (distance per time), using a ratio of heat sources (fuels) to heat sinks (heat required for ignition), with fuels and heat sinks measured in energy per time per surface area. Based on this fire spread rate, the Rothermel model then calculates fireline intensity and flame length. Inputs to the Rothermel model include fuels, topography, and wind speed and direction (which are a conservative assumption of 20 ft/min upslope in the CECS model). Post-treatment % change in flame length can be estimated by crosswalking project treatments with management scenarios in CECS that have varying degrees of vegetation removal.

- o Geospatial Scale**:** The CECS tool can be used at the project scale, but outcomes are intended to be averaged across the entire treatment polygon and not interpreted pixel by pixel.
- o Frequency of Reporting: Annual
- o Science Lead: Hugh Safford Lab, UC Davis

13. Performance Metric: Capital Investments in Wood Processing Facilities

Relevant Activities:

- Thinning
- Postfire Recovery

Biophysical Model and Data Requirements: Local (<50 miles) wood processing facility managers can be surveyed every two years to ascertain where capital investments have been made in those facilities, indicating a measure of economic growth. The total number of businesses using woody material from the Eldorado National Forest is likely <20 or potentially <10, making tracking Total Dollars Invested in Wood Processing Facilities at the site level fairly straightforward.

Geospatial Scale: Facility-level
Frequency of Updating: Approximately every two years.

Science Lead: CALFIRE

Outcome: Improved Forest Resilience

Resilience Pillar: Forest Resilience; Fire Dynamics; Biodiversity Conservation

14. Performance Metric: Proportion of Max Stand Density Index (SDI)

Relevant Activities:

- Thinning
- Prescribed Fire
- Invasive Species/Integrated Pest Management
- Reforestation
- Postfire Restoration (Streambank Stabilization)

Biophysical Model & Data Requirements

The stand density index (SDI) is the calculation of the size (DBH) and number of trees (TPA or trees/acre in a stand (North et al., 2022, Woodall et al., 2007, Reineke, 1993). The formula is

$$SDI = \sum TPI\left(\frac{DBH}{25.4}\right)^{1.6}$$

SDI = Stand density index

DBH = diameter and breast height

TPA = trees/acre

SDI is widely used by foresters and can be used as a relative measure of how crowded a stand is or to show competition between trees (North et al., 2022). SDI data is provided in the Regional

Resource Kits and will be updated regularly. The stand condition will be evaluated as a proportion of max SDI or at a given location, the percent deviation from the max SDI.

Geospatial Scale: Stand to landscape. 30m rasters

Frequency of Reporting: Annual (According to the Task Force)

Science Lead: Sierra Nevada Conservancy, Safford Lab

15. Performance Metric: Fire Return Interval Departure (FRID)

Relevant Activities:

- Thinning
- Prescribed Fire
- Invasive Species/Integrated Pest Management
- Reforestation
- Postfire Restoration (Streambank Stabilization)

Biophysical Model & Data Requirements

A seminal paper on California FRID mapping by Safford and Van de Water (2014) is here. FRID allows managers to target areas at high risk of threshold type responses owing to altered fire regimes and interactions with other factors FRID quantifies the difference between current and presettlement fire frequencies and is a commonly used metric to understand fire return intervals in a landscape. More references are available in the RRK metric dictionary. FRID is updated annually at the statewide level. Fires must be a certain size to be included.

According to the RRK metric dictionary 'Contemporary FRIs were calculated using the California Interagency Fire Perimeters database (maintained by the California Department of Forestry and Fire Protection (CAL FIRE-FRAP). The vegetation type stratification was based on the US Forest Service eVeg map (USDA Forest Service, Mapping and Remote Sensing Team) for California from the year 2011, with the vegetation typing ("CALVEG") grouped into 28 pre-settlement fire regime (PFR) types, as defined by Van de Water and Safford (2011).

- Geospatial Scale:
- Frequency of Reporting:
- **Science Lead:** Sierra Nevada Conservancy, Safford Lab

16. Performance Metric: Time Since Last Fire

Relevant Activities:

- Thinning
- Prescribed Fire
- Invasive Species/Integrated Pest Management
- Reforestation
- Postfire Restoration (Streambank Stabilization)

Biophysical Model and Data Requirements:

A measure of fire frequency derived from the number of years since the last recorded fire. Time since last fire is available on an annual basis from the Fire and Resource Assessment Program (FRAP).

Geospatial Scale: Large Trees = 300 m raster, Max SDI = 300 m raster

Frequency of Updating: Annually to every five years.

Science Lead: Sierra Nevada Conservancy, Safford Lab

17. Performance Metric: Standing Non-Merchantable Biomass (dry weight tons/acre)

Relevant Watershed Activities:

- Thinning

Biophysical Model and Data Requirements: The metric measures total amount of existing biomass volume (dry weight tons/acre) from all live tree crowns and trees < 10" dbh (Metric Dictionary, 2022). It does not include a shrub component, which can be a significant contributor to total biomass. The data comes from F3 data outputs and is available in the Sierra Nevada Regional Resource Kit.

Geospatial Scale**:** 300m raster
Frequency of Updating**:** Approximately every two years.

Science Lead: CALFIRE

Outcome: Workforce Development

TCSI Resilience Pillars: Economic Diversity, Social & Cultural Well-being

18. Performance Metric: Local Contracting Capacity

Relevant Activities:

- Thinning
- Prescribed Fire
- Meadow Integrity
- Riparian Restoration
- Invasive Species Management
- Reforestation
- Postfire Restoration
- Slope & Ground Stabilization

Biophysical Model and Data Requirements:

Local (<50 miles) contractor surveys can be undertaken to ascertain several socioeconomic indicators: Labor Hours and Staff Supported Annually (Jobs), Number of Contracts Supported by through Ecological Restoration, and Contract Value (Dollars Awarded and/or Forest Products Cut Value). Additional questions can be included in contractor surveys to reflect recruitment and training efforts- namely, Number of Participants Hired/Trained, and Licenses and Certifications Awarded.

- Geospatial Scale: Placer and Eldorado County Socioeconomic Area of Influence
- Frequency of Reporting: Five-year rolling annual average
- Science Leads: TBD, local collaborative or academic institutions in partnership with TCSI are being contacted.

Science Leads: CALFIRE