

EVM Effectiveness analysis

August 2022



Executive Summary

➤ Executive Summary:

The objective of this analysis is to provide a measure of the effectiveness of Enhanced Vegetation Management (EVM) work since the program started in 2019.

Approach:

The analysis focuses on EVM pole-to-pole segments (PtPS), which allows to precisely capture EVM work start and completion dates. PtPS are then aggregated at the Circuit Segment (CS) level (or circuit protection zones), and event incidence rates are computed for each CS where EVM work has been performed.

The analysis aims at comparing incidence rates on a 1-year window preceding EVM work, with the incidence rate on the 1-year window immediately following work completion and verification.

More than 180k work-completed PtPS were considered in the analysis, which cover about 4750 miles.

Results:

A paired T-test has been conducted to compare the before and after EVM incidence rates across the same pool of CS, which allows to eliminate random inter-CS variations (such as tree density).

Ignitions (8 events):

Incidence rate of ignitions is 80% lower after EVM, with a test P-value of 5.26%. Using a $\alpha = 5\%$ significance level, it cannot be concluded that EVM reduces the ignition incidence rate in a statistically significant way.

Outages + PSPS Damages and Hazards (319 events):

Incidence rate of outages and PSPS D&H is 58% lower after EVM, with a test P-value of 9.56%. Using a $\alpha = 5\%$ significance level, it cannot be concluded that EVM reduces the outage incidence rate in a statistically significant way.

Incidence rate of outages and PSPS D&H *under blue sky conditions* is 76% lower after EVM, with a test P-value of 3.97%. Using a $\alpha = 5\%$ significance level, it can be concluded that EVM reduces in a statistically significant way the outage incidence rate on blue sky weather signal days.

Scope and methodology

➤ Definitions:

- Poles-to-pole segments (PtPS): EVM segments
- Circuit Segments (CS): Latest and official vintage of Circuit Segments (former Circuit Protection Zones)

➤ Data sources:

From Foundry:

- Evm PtPS data: *conductorsegment_workflow_base*
- Ignitions data: *ignitions_2013_and_beyond_All_ignitions_clean*
- Outages data: *agg_outages*
- PSPS damage and Hazard: *PSPS_Damage_Hazard_Data_Clean*
- Pixels and CS geometries: *WDRM_V3_evm_pixels_weighted_px_assignments*

➤ EVM effectiveness Scope:

- ~900k pole-to-pole segments, 28k total miles
- ~1000 Circuit Segments with EVM-worked PtPS
- Events (Outages/Ignitions) starting January 2018 to August 2022

➤ Methodology overview

1. Mapping PtPs to CS
2. Aggregate PtPs information at CS level
 - Number, miles of PtPS segments
 - EVM work start/end date for each PtPS
3. Event (ignition / outages) mapping to closest PtPS
4. Statistical analysis at CS level

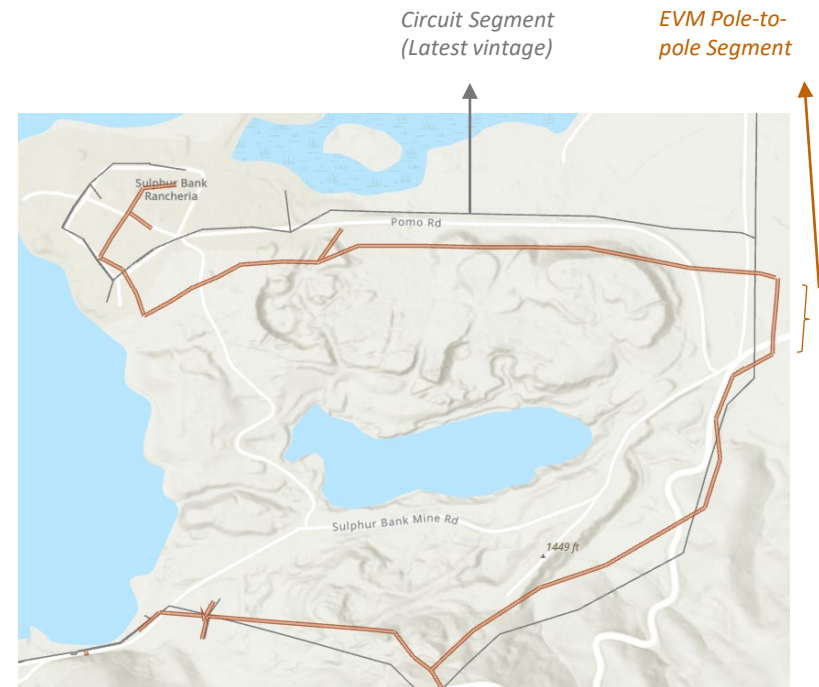


Figure 1: Example of differences between EVM PtPS geometries and latest CS vintage

Mapping PtPS to Circuit Segments

➤ Why start at PtPS level:

- Allows to access precise EVM work start/end dates
- Small units allows for higher CS level aggregations while retaining precise EVM work information

➤ Mapping:

- PtPS are mapped to the closest CS within a ~120m radius
- In case of multiple CS within radius, closest CS is chosen (based on average shortest distance across 10-equally spaced points along PtPS)

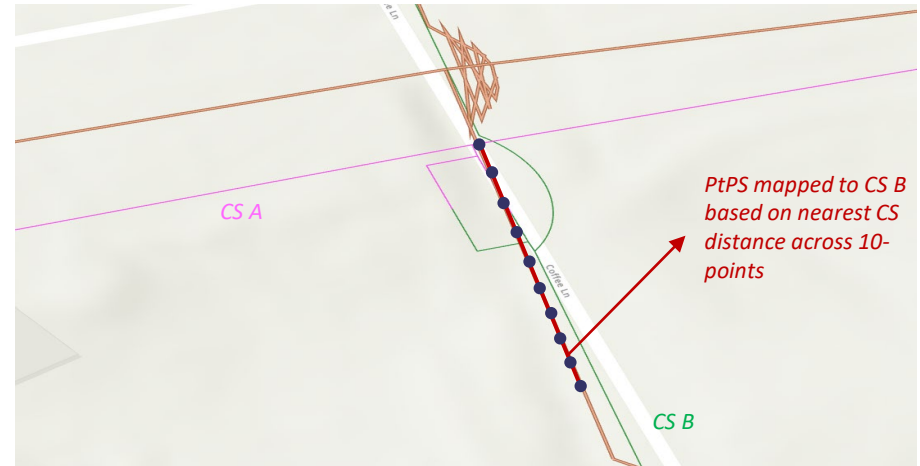


Figure 2: Example of CS mapping based on shortest 10-point distance

➤ PtPS with no CS within radius:

- Account for ~5% to 8% of all PtPS
- Most are outside HFTD, with no nearby CS
- Ignored in the present analysis (can be added as additional independent CS)

➤ Results (base for following analysis):

91.3% of all PtPS mapped to CS:

- 830K PtPS / 908K total
- 25.6k miles / 28k total

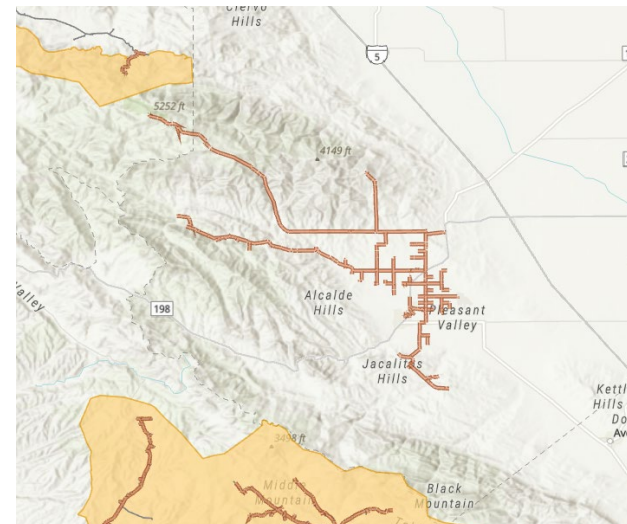


Figure 3: Example of PtPS with no reference CS, outside HFTD (PtPS belong to older vintage CPZ = COALINGA NO 2 11059260)

Scope of analysis and methodology

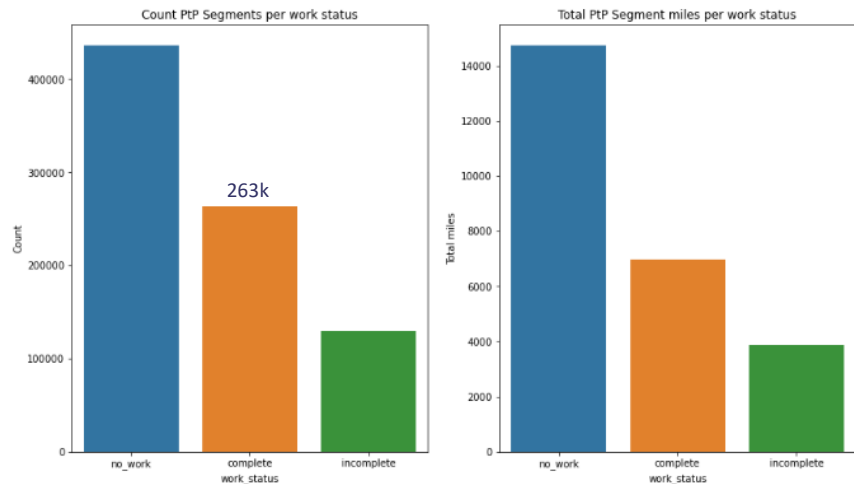
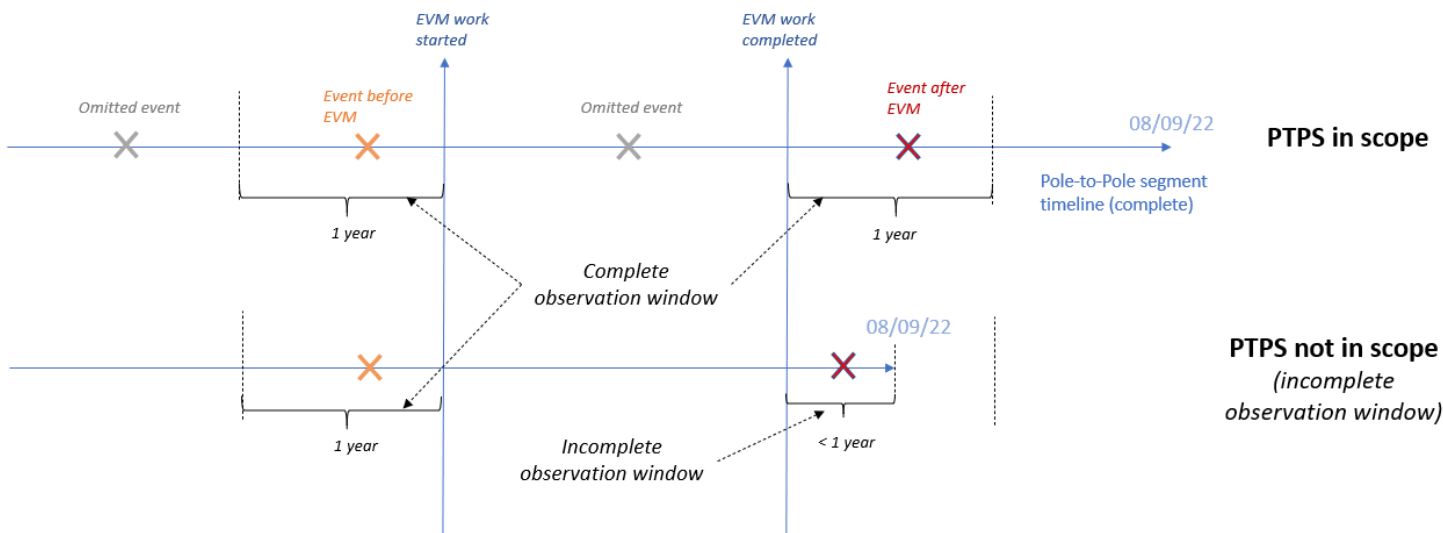


Figure 4: PtPS count and miles based on work status

Scope of Analysis:

- PtPS with EVM work completed (263K)
 - Allows before VS after treatment comparison on same segment (robust paired T-test)
 - Random interPtPS variation is eliminated
- PtPS with complete 1-year observation window before and after EVM (181K)
 - Covers full cycle (winter and fire season)
 - Analysis can be refreshed every day, as EVM work completed 1 year ago becomes available
- Limitations:
 - All EVM work completed in last rolling year is out-of-scope.
 - Omits events outside of observation windows



Scope and Methodology - Summary

Summary of Scope and Methodology:

- 181K PtPS included in analysis – (4750 miles)
 - EVM Work completed PtPS only
 - Complete 1-year observation window before/after EVM
- PtPS aggregation at CS level – (~1000 Circuit Segments)
 - Number of events before and after EVM are computed at CS level
 - Total in-scope PtPS miles computed at CS level
- Statistical test at CS level:
 - Metric of interest:
incidence rate = Num of events / year / miles
 - Comparison of mean incidence rate **before** EVM across all CS with mean incidence rate **after** EVM across all CS
 - Outage tests broken down by vegetation causes (Tree failure VS other veg causes)

Events considered

Ignitions

- 743 ignitions:
 - January 2018 – present
 - Vegetation caused
 - Excluding ig. on secondary conductors

- 360 mapped to PtPs (~120m radius)
 - 230 unworked PtPS
 - 74 incomplete PtPS
 - 56 work-completed PtPS

- **8 ignitions** on in-scope PtPS (within observation windows)

Outages

- 16703 outages:
 - January 2018 – present
 - Vegetation caused
 - Vegetation Inspected
 - Excluding secondary conductor outages

- 9966 mapped to PtPs (~120m radius)
 - 6753 unworked PtPS
 - 2207 incomplete PtPS
 - 1006 work-completed PtPS

- **299 outages** on in-scope PtPS (within observation windows)

PSPS damages and hazards

- 591 damages & hazards:
 - January 2018 – present
 - Vegetation caused
 - PSPS inspected/QC
 - Excluding secondary conductor D&H

- 451 mapped to PtPs (~120m radius)
 - 227 unworked PtPS
 - 146 incomplete PtPS
 - 78 work-completed PtPS

- **20 D&H** on in-scope PtPS (within observation windows)

Ignition T-test results

Ignitions

Test Case	Num ig before	Num ig after	Mean incidence rate before EVM	Mean incidence rate after EVM	Delta	Paired t-test-stats	P-value
in-scope PtPS	6	2	0.00053	0.0001	-81%	1.621631	5.26%
work-incomplete PtPS*	8	11	0.004677	0.004048	-13%	0.205086	41.88%

Table 1: Paired t-test results for mean ignition incidence rate on in-scope PtPS (aggregated at CS level)

Results and interpretations (using $\alpha = 5\%$ significance level):

One cannot conclude that EVM reduces the ignition incidence rate with a type I risk of 5%, for both in-scope and work-incomplete cases, in a statistically significant way.

**work-incomplete PtPS:*

Test done on work-incomplete PtPS by setting the post 1-year observation window 6 months after the work start date. It comprises 95K PtPS which totalize 2460 miles.

Outages / PSPS D&H T-test results

Outages / PSPS D&H

Test Case	Num event before	Num event after	Mean incidence rate before EVM	Mean incidence rate after EVM	Delta	Paired t-test-stats	P-value
all in-scope outages + PSPS D&H	207	112	0.177204	0.074864	-58%	1.309367	9.54%
in-scope outages only	203	96	0.175557	0.071006	-60%	1.338034	9.06%
outages - tree failure	138	67	0.092191	0.030245	-67%	1.473271	7.05%
outages - other	58	27	0.082007	0.04068	-50%	0.895457	18.54%
*all-scope work-incomplete PtPS	501	419	0.554343	0.124606	-78%	1.413946	7.89%

Table 2: Paired t-test results for mean outage/PSPS D&H incidence rate on in-scope PtPS (aggregated at CS level)

Results and interpretations (using $\alpha = 5\%$ significance level):

One cannot conclude that EVM reduces the outage/PSPS D&H incidence rate in a statistically significant way, with a type I risk of 5%, for any case listed above.

**all-scope work-incomplete PtPS:*

Test done on work-incomplete PtPS (Outages + PSPS D&H) by starting the post 1-year observation window 6 months after the work start date. It comprises 95K PtPS which totalize 2460 miles.

Outages / PSPS D&H T-test results

Outages / PSPS D&H per Weather signals

Case	Num outspss before	Num outspss after	Mean incidence rate* before EVM	Mean incidence rate* after EVM	Delta	Paired t-test-stats	P-value
all	207	112	0.1772	0.0749	-58%	1.3094	9.54%
WinterStorm + LowSnow + Lightnings	125	47	0.686	0.5632	-18%	0.2493	40.16%
BlueSky	49	21	0.0364	0.0089	-76%	1.7561	3.97%
Wind*	20	39	0.4502	0.2062	-54%	0.8284	20.38%

Table 3: Paired t-test results for mean outage/PSPS D&H incidence rate on in-scope PtPS (aggregated at CS level) for different weather signal

Results and interpretations (using $\alpha = 5\%$ significance level):

One can conclude that EVM reduces the outages/PSPS D&H incidence rate on *BlueSky* days with a type I risk of 5%.

One cannot conclude that EVM reduces the outage/PSPS D&H incidence rate with a type I risk of 5%, on WinterStorm + LowSnow days or Wind days.

*Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS

**Incidence rate = Num of events / year of weather signal / miles.

Mean Incidence rate = Mean (Incidence rate) across Circuit Segments

Outages / PSPS D&H T-test results

Tree failure related Outages per Weather signals

Outage subsets: tree failure (veg_cdolip_cause = "Tree - fell into line")							
Case	Num outspss before	Num outspss after	Mean incidence rate before EVM	Mean incidence rate after EVM	Delta	Paired t-test-stats	P-value
All (tree failure outages)	138	67	0.0922	0.0302	-67%	1.4733	7.05%
WinterStorm + LowSnow + Lightnings	100	35	0.5661	0.1485	-74%	1.1103	13.36%
BlueSky	26	11	0.0176	0.0028	-84%	1.2284	10.98%
Wind*	7	18	0.0758	0.1440	90%	-0.5841	72.03%

Table 4: Paired t-test results for mean **tree-failure**-outage incidence rate on in-scope PtPS (aggregated at CS level) for different weather signals

Results and interpretations (using $\alpha = 5\%$ significance level):

One cannot conclude that EVM reduces the tree-failure related outage incidence rate with a type I risk of 5%, on the different weather signals outlined in table 4.

*Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS

**Incidence rate = Num of events / year of weather signal / miles.

Mean Incidence rate = Mean (Incidence rate) across Circuit Segments

Outages / PSPS D&H

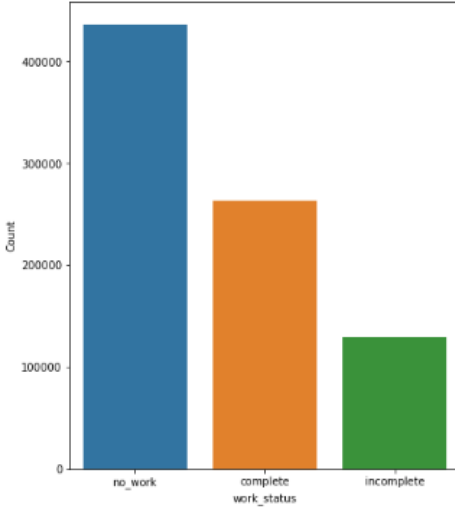
Outages / PSPS D&H across whole EVM system

Case	Num outpsps before	Num outpsps after	Incidence rate on whole system before EVM	Incidence rate on whole system after EVM	Delta
all	207	112	0.0436	0.0236	-46%
WinterStorm + LowSnow + Lightnings	125	47	0.159	0.0944	-41%
BlueSky	49	21	0.0144	0.0063	-56%
WIND	20	39	0.0665	0.1098	65%

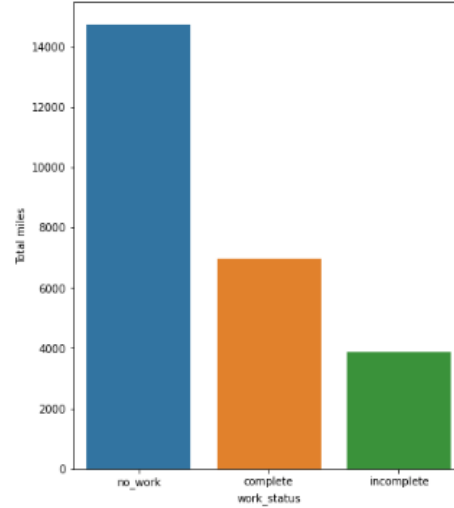
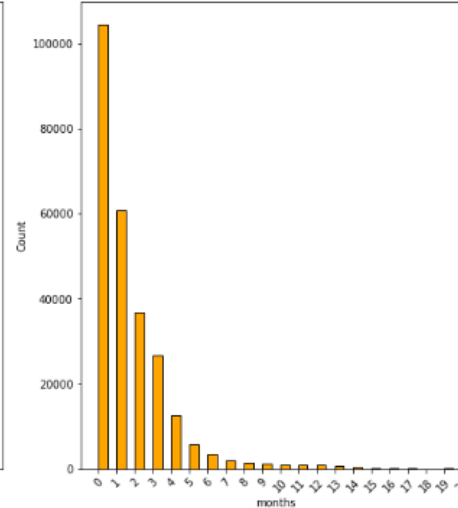
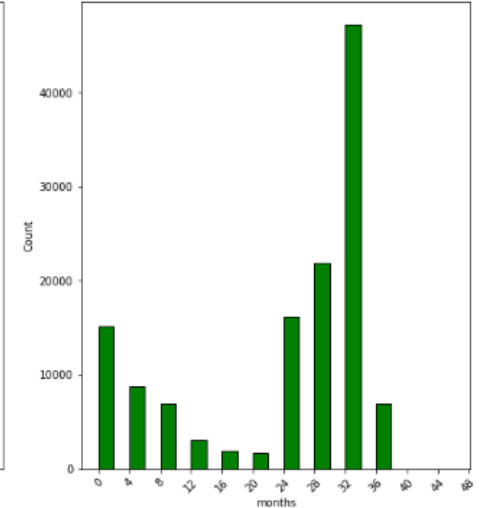
Table 5: Incidence rates per weather signals on whole EVM work-completed system (no aggregation at CS level)

Appendix A: PtPS statistics

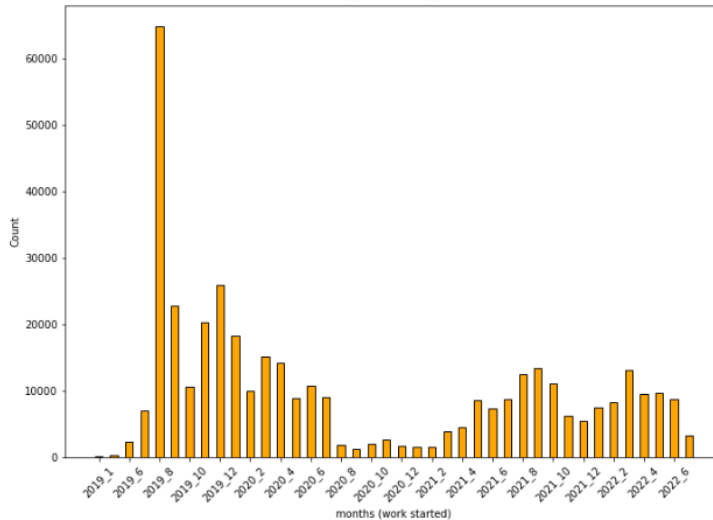
Count PIP Segments per work status



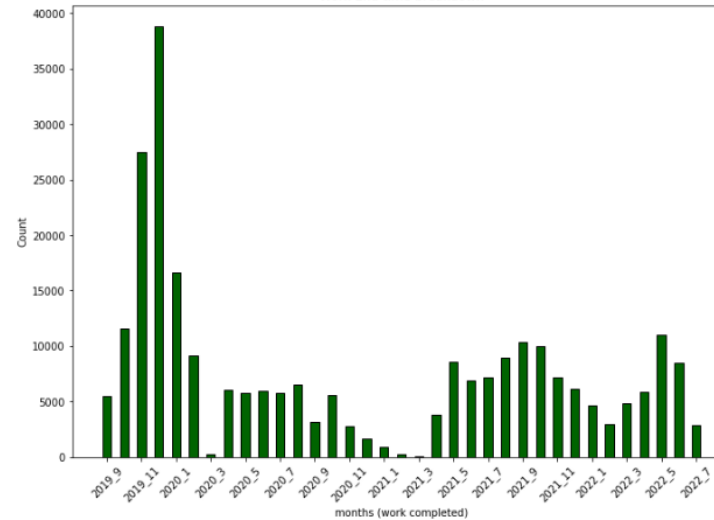
Total PIP Segment miles per work status


COMPLETE WORK:
months between start and end of work

INCOMPLETE WORK:
months since start of work


Work Start time breakdown



Work End time breakdown



Appendix B: CS aggregation

	wc_ptps_count	total_wc_ptps_miles	num_ptps_started	num_ptps_completed	outpsps_count	Num_outpsps_before	Num_outpsps_after	event_rate_before	event_rate_after
cs_name									
WILLITS 110434008	974	16.437096	974	974	22.0	12.0	10.0	0.730056	0.608380
WILLITS 1104934	783	16.007924	783	783	9.0	6.0	3.0	0.374814	0.187407
MARIPOSA 21019400	1194	22.597037	1194	1194	9.0	4.0	5.0	0.177014	0.221268
WILLITS 1104504	857	15.974573	857	857	8.0	4.0	4.0	0.250398	0.250398
COTTONWOOD 11031348	988	25.981449	988	988	5.0	5.0	0.0	0.192445	0.000000
SILVERADO 2104515946	563	8.538726	563	563	4.0	2.0	2.0	0.234227	0.234227
WOODACRE 1101404	673	7.341404	673	673	4.0	1.0	3.0	0.136214	0.408641
WEST POINT 11024790	404	5.146943	404	404	4.0	3.0	1.0	0.582870	0.194290
CALISTOGA 11015934	812	14.514448	812	812	4.0	2.0	2.0	0.137794	0.137794
CURTIS 170539256	765	17.764139	765	765	4.0	3.0	1.0	0.168880	0.056293

Table 3: Top 10 Circuit Segment with highest outage/PSPS
D&H events

Appendix B: CS aggregation

	wc_ptps_count	total_wc_ptps_miles	num_ptps_started	num_ptps_completed	ig_count	Num_ig_before	Num_ig_after	event_rate_before	event_rate_after
cs_name									
MERCED FALLS 110287352	730	23.380317	730	730	1.0	1.0	0.0	0.042771	0.000000
CALISTOGA 11015934	812	14.514448	812	812	1.0	0.0	1.0	0.000000	0.068897
OLETA 110113478	153	6.910320	153	153	1.0	1.0	0.0	0.144711	0.000000
BELL 1108127062	363	8.336462	363	363	1.0	1.0	0.0	0.119955	0.000000
DEL MONTE 21042762	124	5.756681	124	124	1.0	1.0	0.0	0.173711	0.000000
LAURELES 11112020	834	28.771848	834	834	1.0	0.0	1.0	0.000000	0.034756
CURTIS 170384944	1199	44.179388	1199	1199	1.0	1.0	0.0	0.022635	0.000000
CORNING 110185152	780	21.525141	780	780	1.0	1.0	0.0	0.046457	0.000000
PARADISE 1104457900	470	5.818389	470	470	0.0	0.0	0.0	0.000000	0.000000
PARADISE 110439216	113	1.549727	113	113	0.0	0.0	0.0	0.000000	0.000000

Table 4: Top 10 Circuit Segment with highest ignition events