APPENDIX D – POWER LINE FIRES

D1. Data Sources

D1.1. CDF Fire Season Summaries, 1999-2005

Distribution: Open

Location: http://www.fire.ca.gov/about_factsheets.php/

Description: Description of largest fires in terms of structures lost and acreage burned from 1999 to 2005

Fields: Name, Start date, containment date, County, acres, structures destroyed, cause

D1.2. CDF Fires by Cause

Distribution: Open

Location:
http://www.fire.ca.gov/about_factsheets.php/incidentsandevents_106_2000-2005.pdf

Description: A pie chart detailing the source of wildland fires managed by CDF from 2000 to 2005, as percentages.

Fields: Fire cause only.

D1.3. CDF Largest Fires

Distribution: Open

Location: http://www.fire.ca.gov/about_factsheets.php/20LSTRUCTURES05.pdf and http://www.fire.ca.gov/about_factsheets.php/20LACRES05.pdf

Description: Description of largest historical fires in terms of structures lost and acreage burned prior to 2005

Fields: Name & Cause, Start date, County, acres, structures destroyed, deaths

D1.4. CDF Fire Perimeters

Distribution: Open

Location: http://frap.cdf.ca.gov/projects/fire_data/fire_perimeters/

Description: Comprehensive fire perimeter data.

Fields: Name, acres, agency, cause, year, month, day

Restrictions & Limitations: "include[s] timber fires 10 acres and greater in size, brush fires 50 acres and greater in size, grass fires 300 acres and greater in size, wildland fires destroying three or more structures, and wildland fires causing $300,000 or more in damage."
"The current fire perimeter layer developed by BLM, CDF, NPS and USFS is the most complete digital record of fire perimeters in California. However it is still incomplete in many respects. Fires may be missing altogether or have missing or incorrect attribute data. Some fires may be missing because historical records were lost or damaged, fires were too small for the minimum cutoffs, documentation was inadequate, or fire perimeters have not yet been incorporated into the database. Agencies are at different stages of participation. CDF and the USFS have completed inventory for the majority of their historical perimeters back to 1950, while only 2002 - 2003 fires are currently present for BLM."
"Some duplicates may still exist. Additionally, over-generalization, particularly with large old fires may show unburned "islands" within the final perimeter as burned. Users of the fire perimeter database must exercise caution in application of the data."

Processing: Analyzed with ArcView.

D1.5. Poisson statistics calculator

For determining confidence levels and statistical uncertainties for small values, the Poisson.rb[1] calculator was used (available from M-bar Technologies & Consulting). This calculator estimates the probability of a random event occurring within a specified interval for a given distribution mean. It is used iteratively to determine 90% confidence levels. For a two-tailed distribution, this entails determining the 95% upper and 95% lower interval.

D2. Analyses

D2.1. Historical Fires and Power lines

D2.1.1. Goal

To ascertain whether historically large fire have a greater tendency to be started by power lines.

D2.1.2. Description

We examine the CDF's collection of the largest historical California fires, both in terms of land area burned and in the number of structures destroyed, as described in the data source section D1.3. These are compared against the 2000-2005 tally of fires by cause compiled by CDF (section D1.2).

D2.1.3. Methods

We break the data into two sets: Largest fire by structures lost and largest fires in terms of area. Both are relevant to SPL, since the loss of structures (and human life) leads to a significant and readily measurable liability cost, while the burned area represents a potential threat to San Diego County's natural resources should frequent fires threaten type conversion. The number of power line fires is determined from each of these sets, representing a fraction. The probability that the observed number is due to a statistical fluctuation around the expected number of power line fires determined from the 2000-2005 fire cause analysis is then determined for both sets.

[1] Attached as Poisson.rb

D2.1.4. Analysis

Of the twenty fires in California resulting in the largest loss of structures, three of them were due to power lines. These were:

#	Name	Date	County	Acres	Structures	Deaths
7	**CITY OF BERKELEY**	**September 1923**	**ALAMEDA**	**130**	**584**	**0**
10	**LAGUNA**	**September 1970**	**SAN DIEGO**	**175,425**	**382**	**5**
15	**SYCAMORE *(KITE)***	**July 1977**	**SANTA BARB**	**805**	**234**	**0**

Of the twenty fires in California resulting in the largest acreage burned, three of them were also due to power lines:

#	Name	Date	County	Acres	Structures	Deaths
3	**LAGUNA**	**September 1970**	**SAN DIEGO**	**175,425**	**382**	**5**
8	**CAMPBELL CMPLEX**	**August 1990**	**TEHAMA**	**125,892**	**27**	**0**
12	**CLAMPITT**	**September 1970**	**LOS ANGELES**	**105,212**	**86**	**4**

Since three events out of twenty are observed both for acreage burned and structures destroyed, these have the same statistical significance. This is interesting, because only one fire (Laguna, 1970) is in both sets. Two effects should be noted here. The first is that very large fires will tend to burn more homes due to the fact that they are large. The second is that power lines concentrations are denser in areas where there is also a greater concentration of housing. The size effect will contribute to both data sets, while the population density will contribute only to structures lost.

According to the 2000-2005 fire cause analysis, 3% of wildland fires are caused by power lines. This leads to an expected mean number of power line fire events out of a sample of 20 fire events of 0.6 events. The probability that a distribution with an expected value of 0.6 events will fluctuate to 3 events is 2.3%. If these were two independent distributions, the probability of observing 3 events twice would be .05%. Since the sets are not independent, we cannot make this claim, and it is not straightforward to combine these results. Suffice it to say, the observation that both the number of structures destroyed and the burned acreage results have only a 2.3% probability makes the likelihood that the observations are due to a statistical fluctuation considerably less.

D2.1.5. Limitations

This is a relatively small sample of events, and by their nature as extremes are atypical.

The number we are using as a standard is the fraction of fires caused by power lines between 2000 and 2005. If this number is not historically representative, particularly if the probability of power line fires was greater in the past than in the present, this would make the measured results less significant.

D2.1.6. Conclusions

Of the 20 largest fire events, regardless of whether number of structures lost or the area burned is considered as the metric, three major historical fire events are due to power lines. The probability that any given fire is due to power lines was measured at 3% between 2000 and 2005. Assuming this ratio is historically true, the probability that the observed number of power line fires is a statistical fluctuation for either of the samples is 2.3%. The fact that both samples yielded the same result is even more significant.

From this we can conclude that power line fires are more likely to burn large areas and destroy more homes than fires initiated by other causes.

D2.2. Power line fires in San Diego, 1910-2005

D2.2.1. Goal

To determine the number of power line fires in San Diego County historically and to determine if these are larger than other fire types.

D2.2.2. Description

The working hypothesis is that power line fires will be more destructive because Santa Ana winds will drive both the creation of fires through line failures and faults, and also make it more probable that initial attack by fire services will fail and that the fire will grow to a large size. If this is true, one would expect historical fire data to indicate that fires identified as power line fires will tend to be larger than those of other fire types. We examine historical fire data for San Diego County, provided by the CDF FRAP project (see D1.4) in the form of GIS shapefiles. Statistics for all fires and for power line fires only were obtained.

D2.2.3. Methods

Historical fire perimeter data for San Diego was obtained from the FRAP project of CDF (now CalFire). This is in the form of ESRI shapefiles, which were loaded into the ArcMap program for processing and display. Among the attributes captured in the metadata for each fire is the cause. Power line fires are listed as cause type 11.

The attribute table was exported to an Excel spreadsheet to allow further processing. Upon examination of the data, it was clear that there were some inaccuracies in even well-known fires. To help judge data quality for area burned, the fact that two different measurements of burned area existed in the table was used as a consistency check. One area measurement in acres was that calculated in the initial fire report. The second is the area (in square meters) covered by the perimeter drawn as part of the CDF's post-hoc geocoding of historical fire data. Where no historical area estimate was given, the area of the shape was used. The correct ratio for the area in acres (estimate) to the area in square meters (geocoded shape) is 4047 (acres/m^2). Fluctuations around this value in the dataset are considerable. A few values were extrema, and assumed to be data entry errors. These were examined, and in the few cases where they were significant fires and where other information was available, corrections were made after validating the areas of the fire perimeters with ArcMap. The corrections made by this analysis were:

- The Cedar fire entry had a misplaced decimal point.
- The Border fire of 2004 seemed to have dropped a digit from the recorded fire size.
- The "Lookout" fire of 1976 was reported at 1 acre. This was set to 0 in order to default to the shape area.

Another correction was made because the Laguna fire of 1970 was not listed as a power line-caused fire. Corrected cells are indicated in magenta in the data file, attached below.

CDF_FirePerimetersSDCo_fixed.xls

File D-1 – CDF Fire perimeters for San Diego County, from 1910 to 2005. This includes fire name and cause, as well as the total area burned. Some data have been corrected, and statistical analysis of the fires can be found at the bottom of the spreadsheet[2].

The fire size data were then averaged over the historical period, both for the full data set and for the subset caused by power lines. Another analysis was done selecting fires after 1960, which is closer to the current trends in terms of population pattern and power line density.

D2.2.4. Analysis

The CDF data includes 1,354 wildland fires in San Diego County in a period from the early twentieth century up to 2005. The quality of the perimeters can be gauged from taking the ratio of the reported fire areas to the areas of the perimeters drawn during the geocoding. This presents a fairly wide distribution, implying that area estimates and perimeters should not be taken as exact, particularly for historical fires.

[2] Attached as CDF_FirePerimetersSDCo_fixed.xls

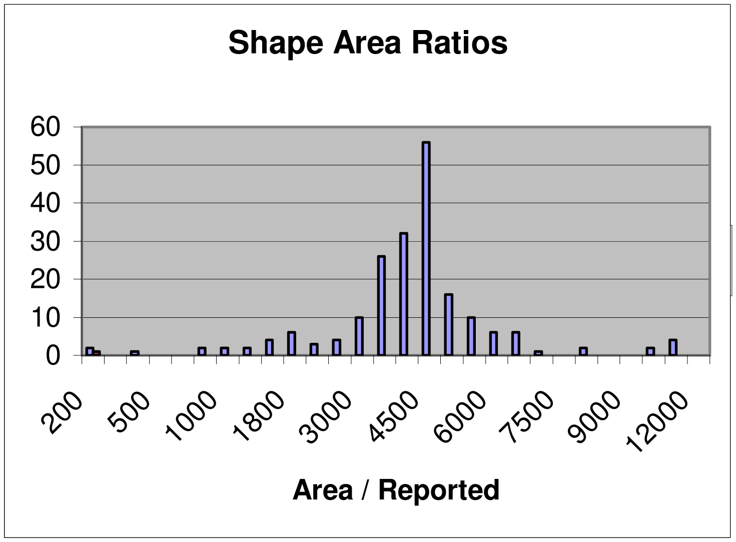

Figure D-1 – This figure displays a histogram of the quality of the CDF fire perimeter data. It shows the distribution of the area subtended by the perimeters drawn by CDF in their geocoding of California fires divided by the fire area reported by fire agencies (as transcribed by CDF). The correct ratio is 4047, which corresponds to the ratio of square meters per acre. If the initial reporting and the geocoding were perfect, all data would be at this value. As can be seen, either the reported areas or the drawn perimeters typically have inaccuracies of 30% or more, with errors of up to 300% not being unusual. A couple of "outliers" were corrected by this analysis as well.

Regardless, this is the best data we have for historical fires. A distribution of their sizes is shown in Figure D-2. Total area reported as burned is 2.77 million acres. The average size of reported fire is 2,042 acres, while the median was 225 acres. This wide discrepancy represents the dominance of large events in determining the damage done by wildland fires. The relatively linear drop between 200 acres and 30,000 acres on a log scale indicates that in this region an exponentially decaying probability distribution is in order, versus the power-law behavior observed in other wildland fire data[3,4]. A strong deviation from this behavior occurs for very large fires, which occur at a greater frequency than that which would be expected from the drop off seen in the statistics for moderately large fires. This could indicate power law behavior at the high end, but the statistics are too poor to either support or refute this hypothesis.

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[3] Moritz, Max A., et. al; Wildfires, complexity, and highly optimized tolerance; Procedings of the National Academy of Sciences of the United States of America; December 13, 2005; vol. 102; 17913

[4] Malamud, B. D., G. Morein, and D. L. Turcotte (1998), Forest fires: An example of self-organized critical behavior, Science, 281, 1840- 1842

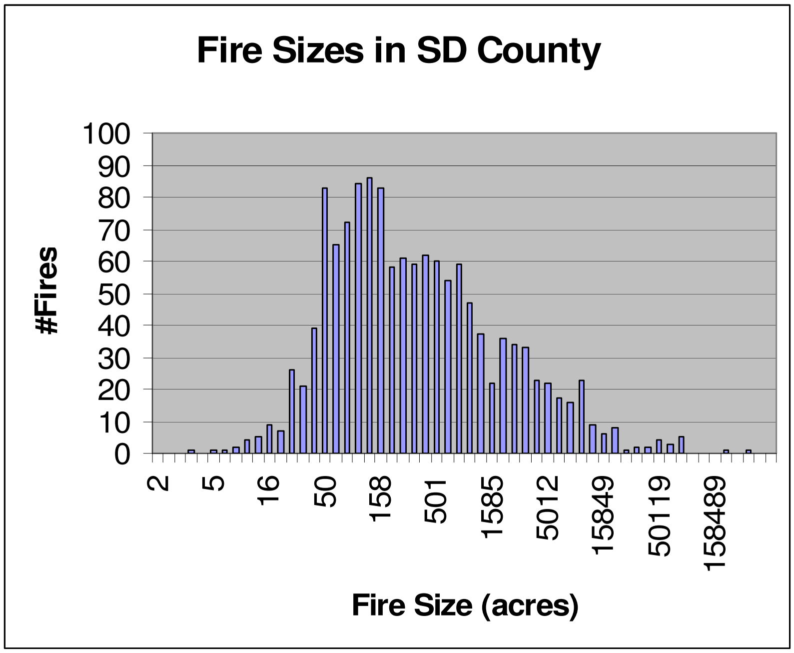

Figure D-2 – This plot shows a histogram of the number of fires falling into each bin of fire size. The x axis is logarithmic, running from 1 to 350,000 acres. Size was determined by reported acreage, when available, or by shape size otherwise.

When we restrict the data to after 1960, when a majority of development and the spread of power lines occurred in San Diego County, the numbers shift somewhat. The average size of fires is 1,923 acres while the median is 149 acres. Total area burned is 1.46 million acres.

Seven fires in the CDF record are known to be started from power lines. All of these occurred in the post-1960 period. These are listed in Table D-1.

YEAR	FIRE	ACRES
1970	LAGUNA	174,158
1993	GUEJIUTO	17,819
1997	LAUREL	702
1996	PALA	467
1999	STEWARD (MAIN)	33.4
2002	PINES	61,690
2005	MILLER	19.7

Table D-1 – Fires in San Diego County caused by power line incidents.

The perimeter of these fires is shown in Figure D-3.

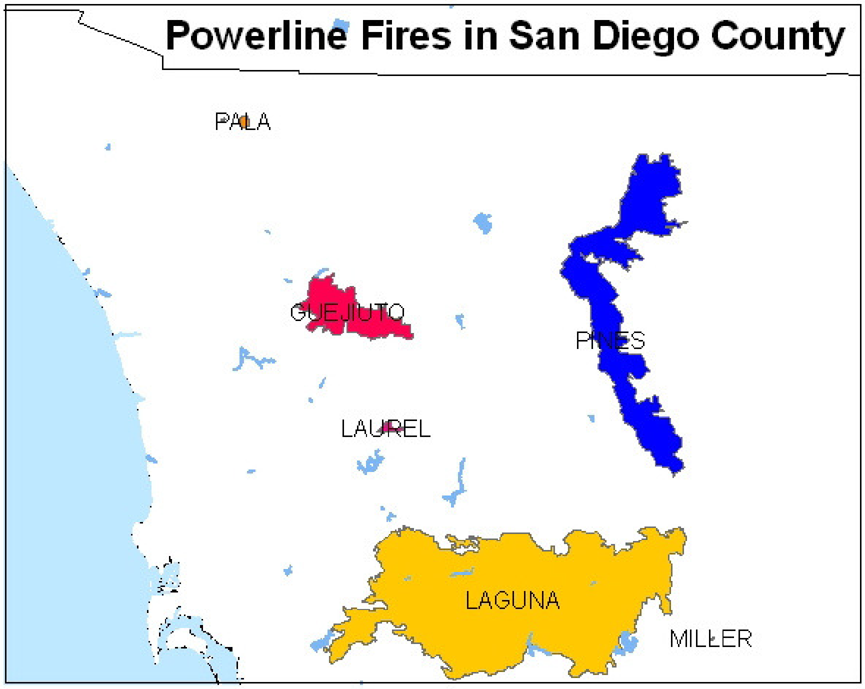

Figure D-3 – Fire perimeters for fires attributed to power lines in the CDF perimeter data.

This number of fires represents less than 1% of all fires since 1960. This is a factor of three less than that for California as a whole as measured in the 2000-2005 time frame (3%). This is possibly explained by the fact that power line fires are predominantly caused by vegetation-line contact, which, due to San Diego's predominant chaparral vegetation type, is less likely due to the smaller number of tall trees than elsewhere in California. However, the average size per fire is 36,000 acres, while the median fire size is 700 acres. The total area burned in power line fires was 255,000 acres, which represents 17% of the total area burned. These results are summarized in Table D-2.

	Fires since 1960	**Power line Fires**	**Ratio**
Number of fires	759	7	.092
Acres burned	1,460,000	255,112	.17
Average fire size	1,924	36,445	19
Median fire size	149	711	4.8

Table D-2 – Power line fires compared to all other San Diego County fires since 1960. It can be seen that power line fires are relatively rare, but very destructive, resulting in 17% of all area burned since 1960.

D2.2.5. Limitations

The disclaimer for the CDF FRAP data warns of inaccuracies (D1.4), and some were observed in a cursory view of the extracted data. When found, these were corrected, but this indicates that there are probably many more remaining in the data set. Averaging over both the good data and bad will lead to a loss of precision in the final result.

Predicting trends from historical data presupposes that historical conditions persist to the present and will persist into the future. Several factors could make future behavior unlike the past:

- The number of power lines has increased as San Diego's population has grown. This factor would make future fires *more* likely.
- Changes in technologies, materials, and procedures by the power company, including vegetation clearance can either *increase* or *decrease* the number of fires.
- Changes in vegetation patterns, through removal, through replacement with invasive species, or shifts due to climate change can either *increase* (invasive species) or *decrease* (vegetation removal) the probability of power line fires.
- Climate change has been predicted to cause longer wildland fire seasons, and drier conditions, thus increasing the overall number of fires[5].

D2.2.6. Conclusions

Examination of historical data reveals that while power line-related fires have been fairly rare in San Diego County, constituting less that one percent of all fires, they have been extremely destructive, burning 17% of all the area burned during this period. This supports the hypothesis that the increased likelihood of power line faults during wind events will make it more likely that power line fires are large, wind-driven fires. Average fire sizes for power line fires have been around 20 times larger than for all fires, while the median fire size has been roughly five times as large, with the discrepancy caused by the fact that fire statistics tend to be driven by the largest catastrophic events. Current population growth trends that increase the number of powerlines and possible impacts of climate change will be effects that will tend to increase this risk and therefore the number of future power line fires.

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[5] Westerling, A. L., et al.; Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity; Science; v. 313; pp. 940-943; 18 Aug 2006