# 1. **Introduction**

BACKGROUND QUOTE

"The Station Fire (2009) in the Angeles National Forest burned an estimated 160,577 acres (650km2 ) and was responsible for the destruction of 209 buildings including 89 homes (Station Fire). During the Fire that lasted from August 26th, 2009 October 16, 2009 scientists from the U.S. Geological Survey (USGS) collected burned soil and ash from 30 different sites. Data was collected by the USGS in order to better understand the way in which burned soil and ash relates to burn intensity, vegetation types, and bedrock geology (Hoefen YEAR.) The organic components of the ash and the burnt soil were also analyzed by the USGS. Total elemental carbon, total elemental nitrogen, inorganic and organic carbon, and organic $\delta$13C and $\delta$15N concentrations were all measured in order to better understand the organic constituents of the soil after the wildfire occurred (included in appendix 1.) However the data and analysis of the organic constituents of the ash and soil were never published. Almost eight years after the Station Fire burned the opportunity to continue the work that the USGS never finished arose. Namely to better understand the dynamics of organics, namely carbon (C) and nitrogen (N) through a timescale analysis by taking into account the preexisting chemical and physical properties of the soil, the biological community, and the severity of the fire on the burnt soils and ash."

## Field Measurements

Sites sampled were visited by a disaster team which was deployed by the USGS to sample soil and ash from the Station Fire of 2009 in the Angeles national forest. The team sampled from 30 sites collecting soil and ash. Top soil (First 5 cm) was collected by the USGS at 23 of the 30 sites, 5 outside of the fire perimeter and 18 inside of the fire perimeter as plotted in Figure 1. Analyses for elemental carbon (C) and nitrogen (N) were measured by the USGS. TALK ABOUT SAMPLING METHODS. Transect, Random Sampling...

In August of 2017 Parker Shankin Clarke and Carl Swindle resampled from the 23 sites visited by the USGS in 2009 for soil sampling. Sites were located using a Garmin MODEL satellite GPS. At each site, random sampling was conducted in a circle with a radius of 15 meters at the most. A Brunton compass was used to measure the slope in degrees. Slope measurements can be seen in Figure 2. Infiltration rate was measured by placing a cylindrical tube into the ground, and filling up the tube with water to a certain height. The infiltration rates were derived by dividing the hight the tube was filled to by the time it took the water to drain through the soil, and can be seen in Figure 3. Soils were sampled from a number of terrestrial biomes including chaparral, desert, pine forest, and riparian zones.

## 2. Methods

### SURFACE AREA FRACTION BY DIAMETER

Soil samples were passed through a 2000 micron ($\mu M$) sieve. Samples were placed in 5.5 molar sodium metaphosphate solution which acted as a dispersing agent. Sampling from soil solutions was conducted using a pipette during centrifugal mixing with a magnetic stir bar. Sampled soil solution was passed through a CILAS 1190 Laser-Particle Size Analyzer, which utilizes Fraunhofer and Mie diffraction theories to assess particle size cumulative distributions. These theories utilize the assumption that particles are perfect spheres, which is rare in soil.

Particle sizes were measured in different intervals. Intervals from $0.04\mu M$ to $0.1\mu M$ are separated by intervals of $0.03\mu M$. Intervals from $0.1\mu M$ to $1.2\mu M$ are separated by $0.1\mu M$. Intervals from $1.2\mu M$ to $2.6\mu M$ are separated by $0.2\mu M$. Intervals from $3\mu M$ to $6\mu M$ are separated by $1\mu M$. Intervals from $6\mu M$ to $9\mu M$ are separated by $0.5\mu M$. Intervals from $9\mu M$ to $20\mu M$ are separated by $1\mu M$. Intervals from $22\mu M$ to $28\mu M$ are separated by $3\mu M$. Intervals from $28\mu M$ to $36\mu M$ are separated by $4\mu M$. Intervals from $36\mu M$ to $40\mu M$ are separated by $2\mu M$. Intervals from $40\mu M$ to $50\mu M$ are separated by $5\mu M$. Intervals from $50\mu M$ to $56\mu M$ are separated by $3\mu M$. Intervals exist at $63\mu M$, and $71\mu M$. Intervals from $75\mu M$ to $100\mu M$ are separated by $5\mu M$. Intervals from $100\mu M$ to $112\mu M$ are separated by $6\mu M$. Interval exists at $125\mu M$, $130\mu M$, $140\mu M$, and $145\mu M$. Intervals from $150\mu M$ to $200\mu M$ are separated by $10\mu M$. Interval exists at $212\mu M$, $242\mu M$, and $250\mu M$. Intervals from $300\mu M$ to $2500\mu M$ are separated by $100\mu M$.

Data was used to produce cumulative distribution function (CDF) plots of the number of grains less than a given diameter in a sample for grains with diameters between 0.04 to 2500 microns in a number of intervals as seen in Figure 4. Each sample was run twice through the CILAS particle size analyzer. The CDF plots the mean values for each interval while the standard deviation is plotted in Figure 5.

Population Density Functions (PDF's) of particles plotted in Figure 6 were taken by taking the difference between an the CDF value for the interval of interest and the value of the next lowest interval fo each interval and dividing that by the difference of diameters from the interval of interest to that of the interval directly below. Zero was subtracted from lowest interval.

In soils, chemical reactions typically occur on grain boundaries. The surface area fraction of each grain size interval was estimated using the equation below.

$$(1)\ SA_j = \frac{((4\pi(d_j/2)^2(CDF_j - CDF_{j-1}))}{\sum_{i=1}^{N}(4\pi(d_i/2)^2(CFD_i - CDF_{i-1}))}$$
$$= ((d_j{}^2(CDF_j - CDF_{j-1}))/\sum_{i=1}^{N}(d_i{}^2(CFD_i - CDF_{i-1}))$$

$SA_j$ is the surface area fraction in the sample that corresponds to grains with the diameters of the interval $j$. $N$ is the number of intervals, each N corresponds to a $d$, which is grain diameter associated with interval, and $CDF$, which is the cumulative distribution value of a given interval and $CDF_0 = 0$ because there are no grains with diameters zero microns or less. Both $i$ and $j$ correspond to different intervals. Estimates of surface area fractions were summed over grains with diameter ranges (0-38]$\mu M$, (38-106]$\mu M$, (106-180]$\mu M$ and (180-2000]$\mu M$ and plotted in Figure 7 as percents.

## SOIL ORGANIC MATTER WEIGHT BY GRAIN SIZE INTERVAL

Coarse material was removed from soil samples through a 2000 micron sieve. Samples were then separated by wet sieving through 180$\mu M$, 106$\mu M$ and 38$\mu M$ sieves. Samples in these intervals were placed in 100°C oven to dry for approximately 24 hours and then weighed. Soil organic matter weight percents were measured by loss on ignition for each grain size interval of each sample. Samples were placed into a muffle furnace at 550°C for approximately 6 hours in order to combust organic matter. Samples were then weighed in order to calculate the weight fraction of organic matter present in each sample in each interval. Results from this analysis can be seen in Figure 8.

## CARBON AND NITROGEN MEASUREMENTS

Carbon (C) and Nitrogen (N) weight percents were calculated using an Elemental CHN Analyzer model CDC 440HA with an atropine standard. approximately 10 to 16 milligrams of each sample were weighed out. Two measurements were made on each soil sample. Molar C/N was calculated for each run and plotted in Figure 9 along with the mean molar C:N. The standard deviation wor each run was calculated and plotted in Figure 10. Molar C:N measured by the USGS in 2009 are plotted in Figure 11.

## SOIL pH

Soil pH was measured by mixing 10±0.02 grams of soil with 10 milliliters of water. After sitting for about an hour or so, a pH meter was used to measure pH. Data collected is plotted by sampling site in Figure 12.

## GEOGRAPHIC ERROR

During the sampling in 2017, over-vegetation, and lack of familiarity with the terrain, and difficulty reading field notes (especially 30) made perfectly locating the sampling points difficult in several cases. Thus error was calculated by comparing USGS GPS coordinates with our own and assuming a spherical earth with a radius of 6731 km.

(2)

$$E_{km} = 6731 * Cos^{-1}(Cos(90-lat1) * Cos(90-lat2) + Sin(90-lat1) * Sin(90-lat2) * Cos(lon1-lon2$$

Error calculated in this manner can be seen in Figure 13.

## ANALYSIS OF ROBUST DATA

Samples with standard deviation in molar C:N $\geq 2$ were eliminated form the analysis. Samples with GPS error $\geq 15$ meters from the original site were eliminated form the analysis as well.

## CHANGES IN MOLAR C:N

Change in Molar C:N were calculated by dividing the mean molar C:N value from samples collected August 2016 by the Molar C:N values obtained by the USGS in 2009. Values further away from one correlated to higher degrees of change. Values above one suggest an increase in

Molar C:N, while values less than one suggest a decrease in Molar C:N. A plot of this for sites outside the fire perimeter is present in Figure 14. These changes in C:N are driven by processes that are not directly associated with post fire soil recovery. The range of these values is [0.83-1.04]. Changes win C:N associated with values outside of this range may be driven by LIST SOME POST FIRE CN PROCESSES. A similar plot for sites inside the fire perimeter is present in Figure 15.

## BURNED SAMPLES WITH SURFACE AREA FRACTION DOMINATED BY GRAINS WITH DIAMETERS IN THE 38-106$\mu M$ RANGE

The surface area percentage in sample collected at sites 14, 15, 21, and 26, is dominated by grains with diameters in the 38-106$\mu M$ as seen in Figure 16. These samples are all from inside of the fire perimeter. Molar C:N at sites 14 and 15 has dropped, while the Molar C:N at sites 21 and 26 has remained close to constant. The grains with diameters in the 0-38$\mu M$ range in samples 21 and 26 have up to 1.5X to 3X the organic matter weight as those in 14 and 15. Additionally, sites 14 and 15 has more surface area dominated by grains in the 180-2000$\mu M$ range compared to sites 21 and 26.

## SAMPLES WITH SURFACE AREA FRACTION DOMINATED BY GRAINS WITH DIAMETERS IN THE 180-2000$\mu M$ RANGE

### COMPARING SITE 5 AND SITE 25 (BOTH BURNED)

Surface area fraction estimates over the grain diameter intervals of interest vary by less than 0.5% between site 5 and site 25 as seen in Figure 18. These samples are all from inside of the fire perimeter. The Surface area in both of these samples is dominated by grains with diameters in the 180-2000$\mu M$ range. In these samples, there is little variability in the organic wt% of grains with diameters in the 180-2000$\mu M$ range. Yet the organic matter wt% for grain diameter intervals 0-38$\mu M$, 38-106$\mu M$, and 106-180$\mu M$ in site 25 are about 2.5X, 2X and 6X that of site 5 respectively. Additionally, there has been a significant drop in molar C:N at site 5, while molar C:N has remained close to constant at site 25. Additionally the infiltration rate is 8X faster at site 5 compared to site 25 as seen in Figure 19.

Observation: Looking at the sections titled "SAMPLES WITH SURFACE AREA FRACTION DOMINATED BY GRAINS WITH DIAMETERS IN THE 38-106$\mu M$ RANGE" and "COMPARING SITE 5 AND SITE 25" there is a negative correlation between organic weight fraction of finer grains in the samples and change in molar C:N from 2009 to 2017 (Samples where the finer grains have a higher organic weight fraction tend to show less of a change in molar C:N, but samples with lower organic weight fraction in finer grains tend to show decrease in molar C:N). Despite the presence of this trend in the fine samples with surface area dominated by grains in the 38-106$\mu M$ diameter range and in the relationship between sites 5 and 25 (similar surface area fractions across for grain diameter intervals of interest, but are both have surface area fractions dominated by grains with diameters in the 180-2000$\mu M$ range, different organic...), this trend is not present the majority of coarser sample with surface area fractions dominated by grains with diameters in the 180-2000$\mu M$ range.

$$\int_{ac}^{b} f(x)dx \tag{3}$$

$$\begin{pmatrix} 1 & 1 & 1 \\ 2 & 2 & 2 \\ 4 & 4 & 5 \end{pmatrix}$$

Here is an example of a table:

| Resolution | $\|\|u - u_h\|\|_\infty$ | Order | $\|\|u - u_h\|\|_1$ | Order |
|---|---|---|---|---|
| $16^2$ | $4.29 \times 10^{-4}$ | – | $1.33 \times 10^{-4}$ | – |
| $32^2$ | $9.01 \times 10^{-5}$ | 2.25 | $3.45 \times 10^{-5}$ | 1.95 |
| $64^2$ | $3.22 \times 10^{-5}$ | 1.48 | $9.04 \times 10^{-6}$ | 1.93 |
| $128^2$ | $9.49 \times 10^{-6}$ | 1.76 | $2.29 \times 10^{-6}$ | 1.98 |
| $256^2$ | $2.50 \times 10^{-6}$ | 1.93 | $5.71 \times 10^{-7}$ | 2.01 |
| $512^2$ | $6.18 \times 10^{-7}$ | 2.01 | $1.42 \times 10^{-7}$ | 2.01 |

Table 1. This table is an example that can be used to create other tables.

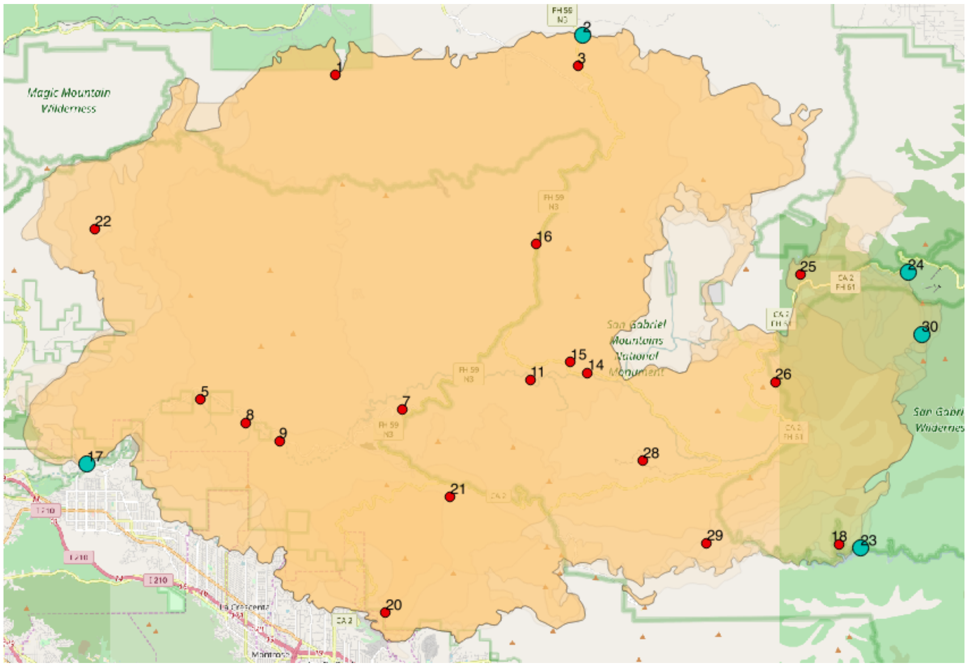


FIGURE 1. The orange area represents the area burned during the Station Fire in 2009. The blue dots represent unburned sampling sites where soil was collected, while red dots represent burned sampling sites where soil was collected.

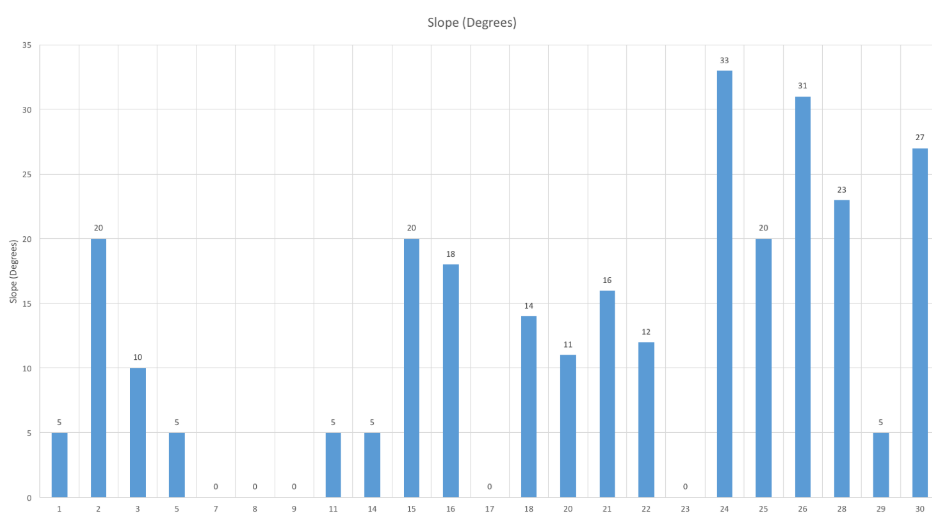


FIGURE 2. Slope at sampling sites measured in August 2017.

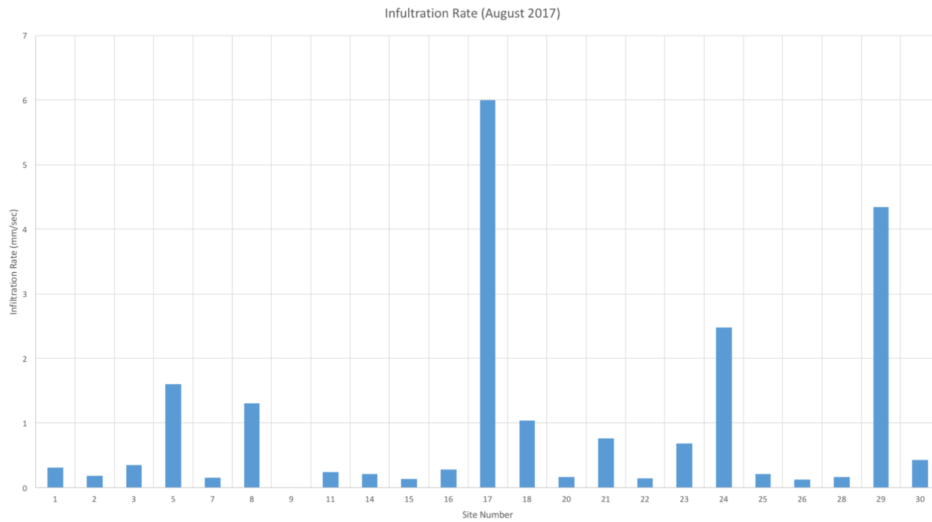


Figure 3. Infiltration rates of soil at sampling sites in August 2017.

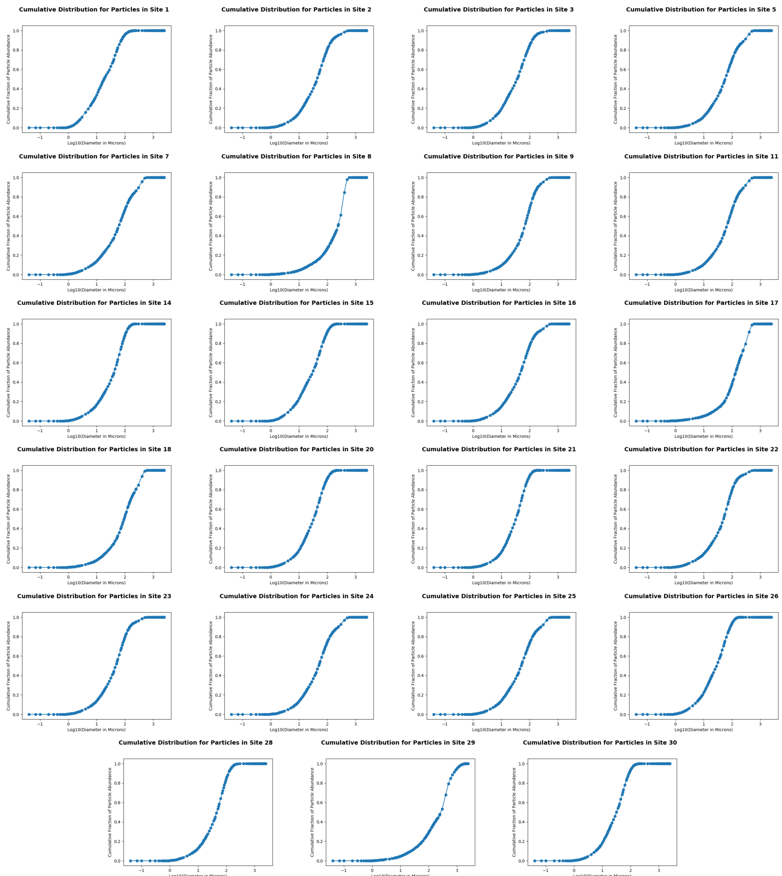


FIGURE 4. Cumulative Distribution Functions derived from CILAS particle size data

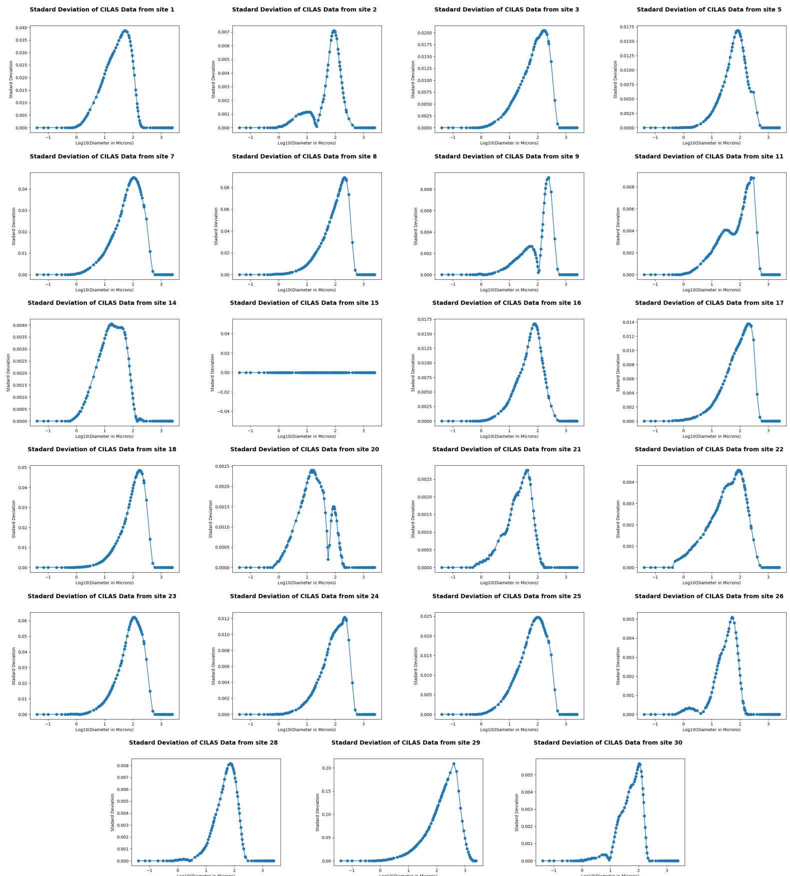


FIGURE 5. Standard deviation of CILAS particle size data (2 runs per sample).

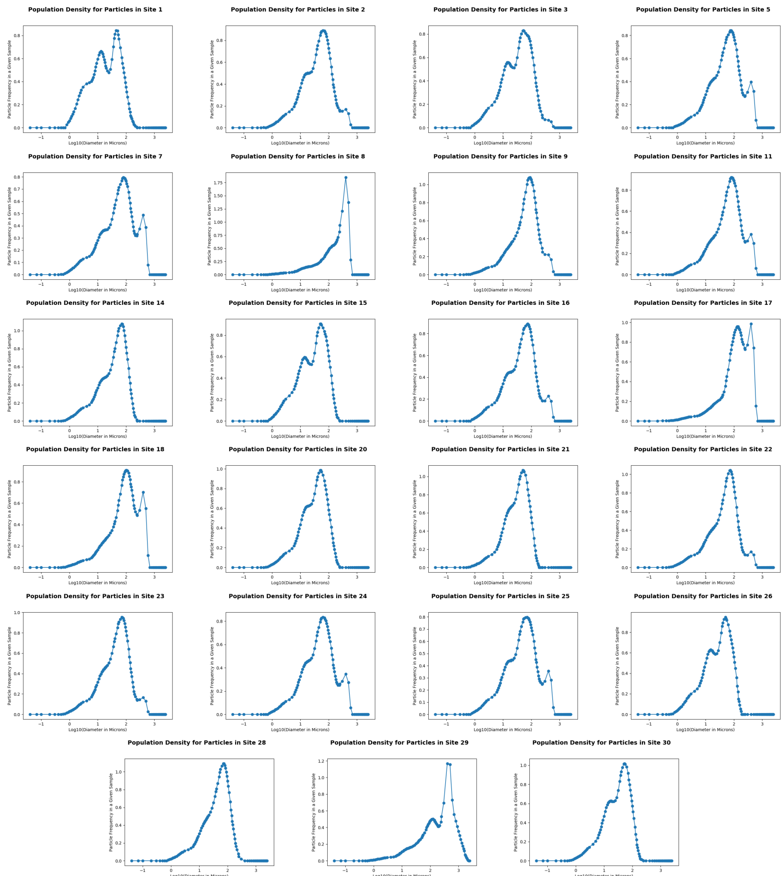


FIGURE 6. Population Density Functions derived from CILAS particle size data

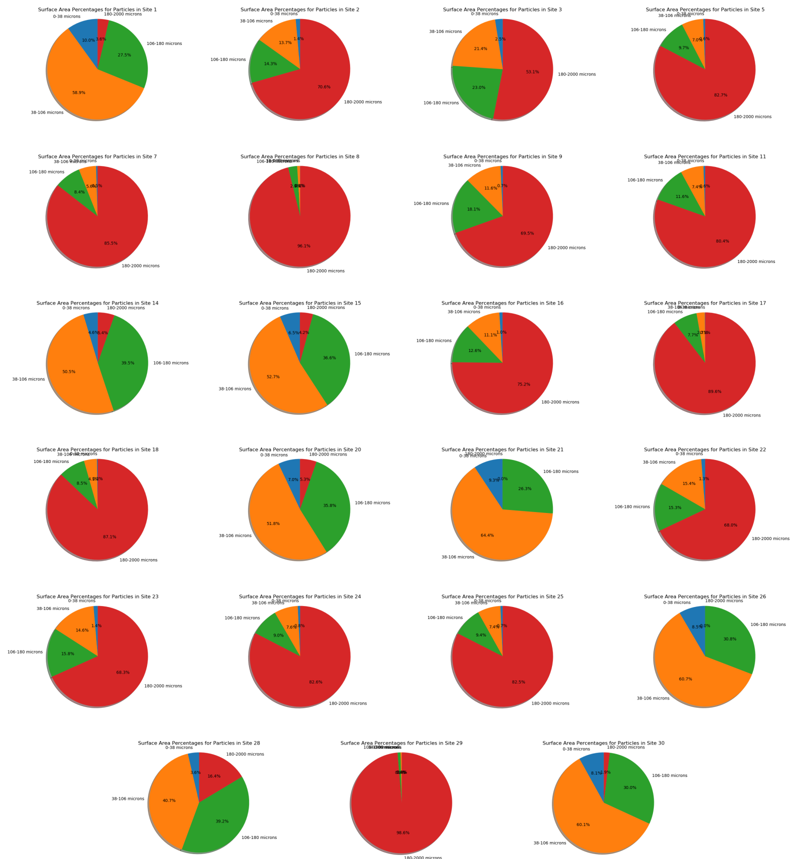

FIGURE 7. Surface Area Percentages derived from CILAS particle size data over 0-38$\mu M$ (Blue), 38-106$\mu M$ (Orange), 106-180$\mu M$ (Green) and 180-2000$\mu M$ (Red) grain diameter intervals

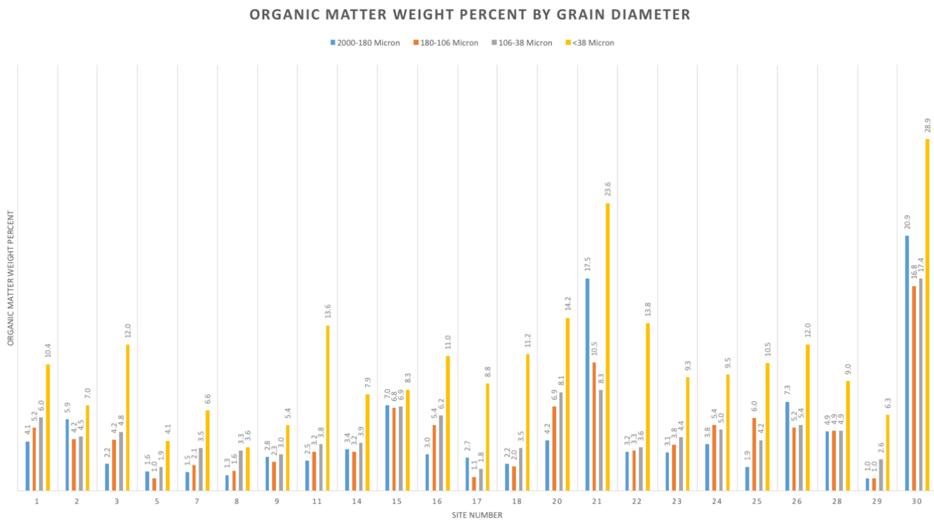


FIGURE 8. Organic Matter weight percents by grain diameter from soils sampled in August 2017.

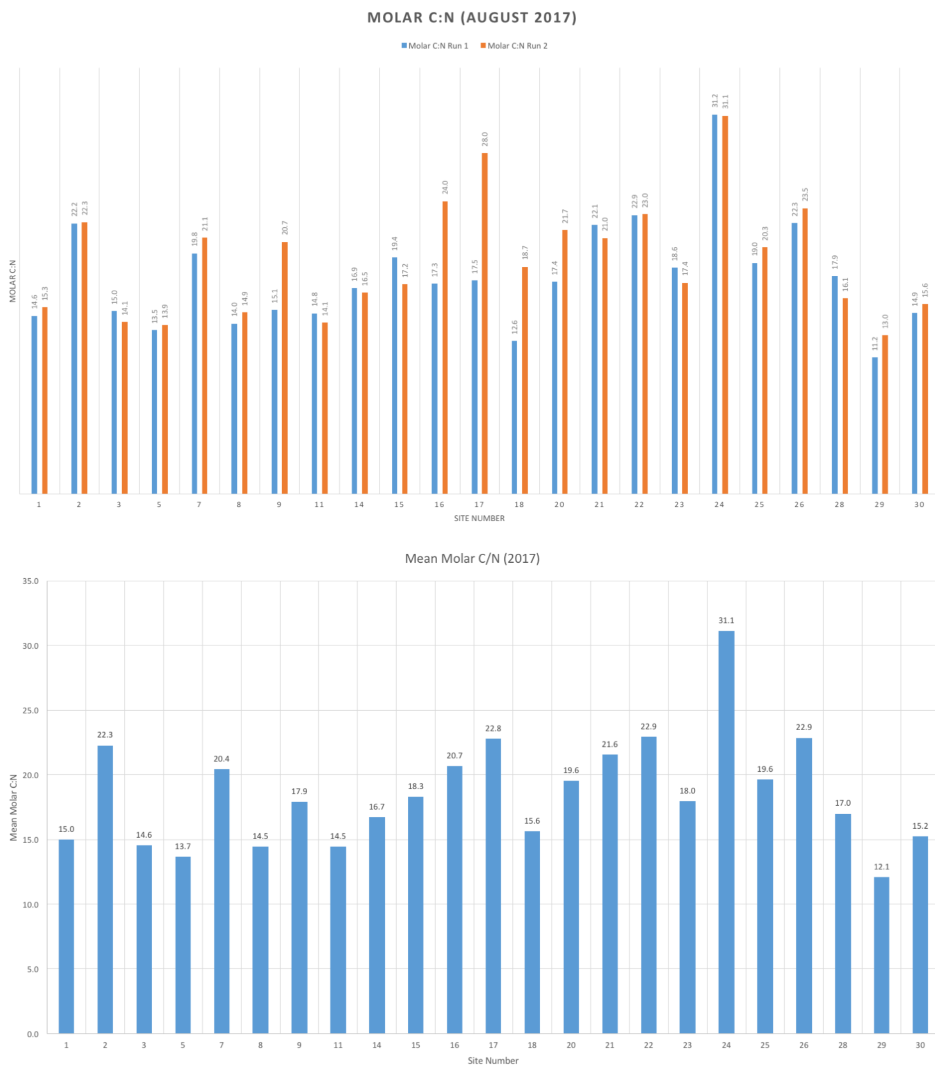


Figure 9. Molar C:N calculated with Elemental-CHN-Analyzer-data from samples collected in August 2017.

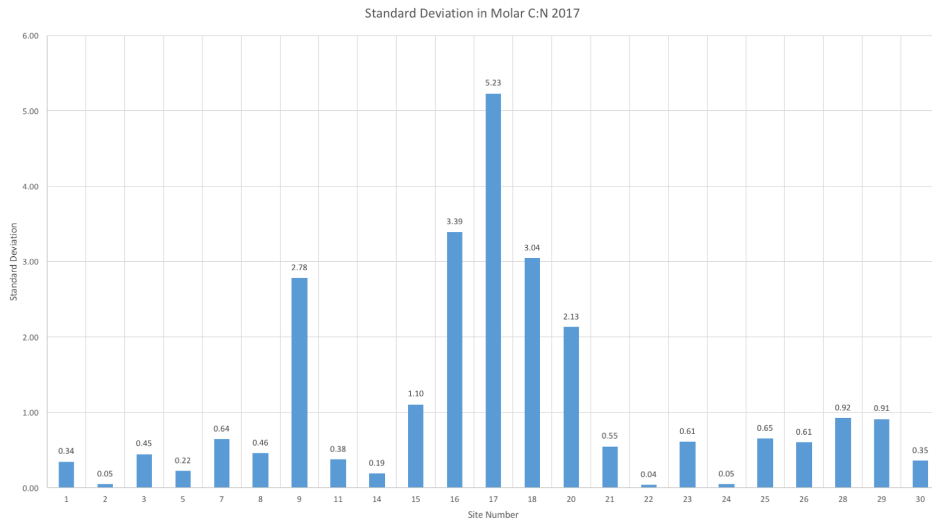


FIGURE 10. This plot shows the standard deviation between molar C:N from Run 1 and Run 2 of the samples on the CHN analyzer. Note the standard deviation is greater than 2 for sites 9, 16-18, and 20. This deviation from the mean molar C:N shows that the data from sites 9, 16-18, and 20 is not robust, and thus, it will not be used for analysis.

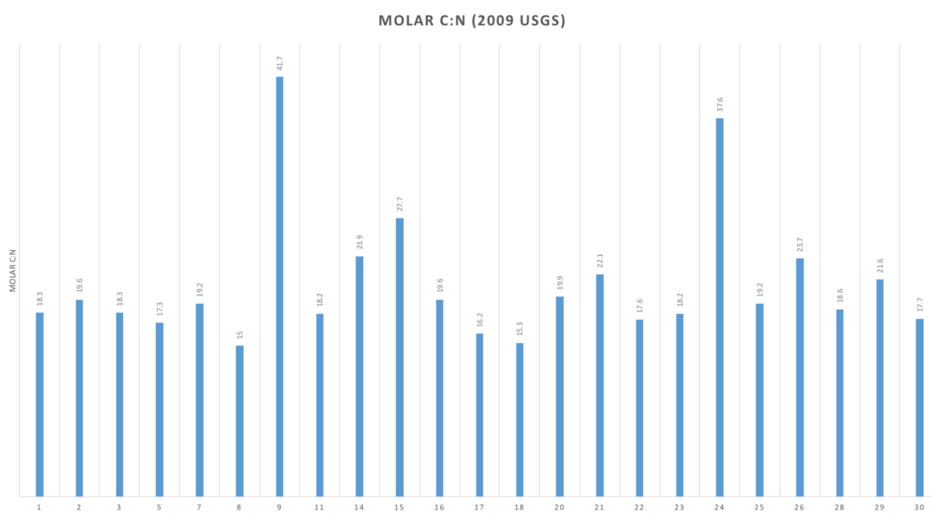


FIGURE 11. Molar C:N measurements measured by the USGS from samples collected in 2009 during the Station Fire

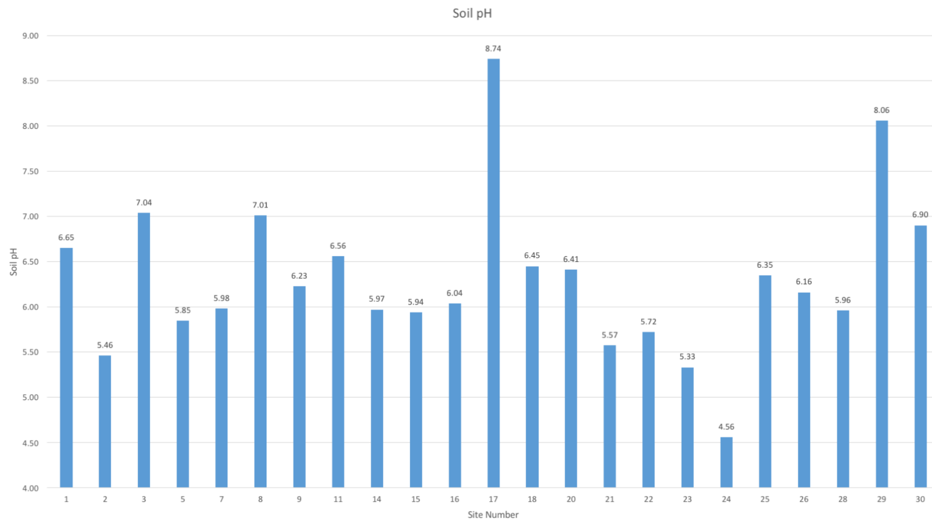


FIGURE 12. Soil pH from soils sampled in August 2017.

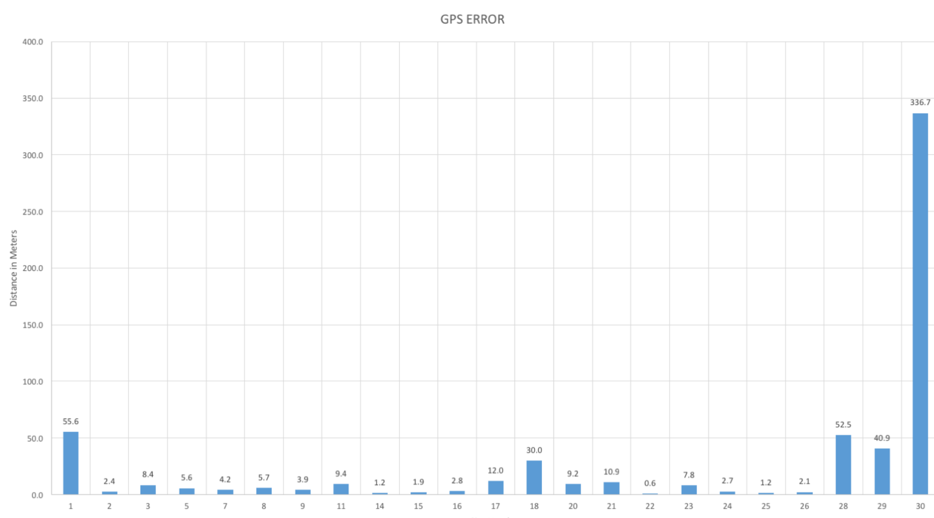


FIGURE 13. Gps offset in meters, (Site 30 gps coordinates were difficult to read, so this error is likely a maximum)

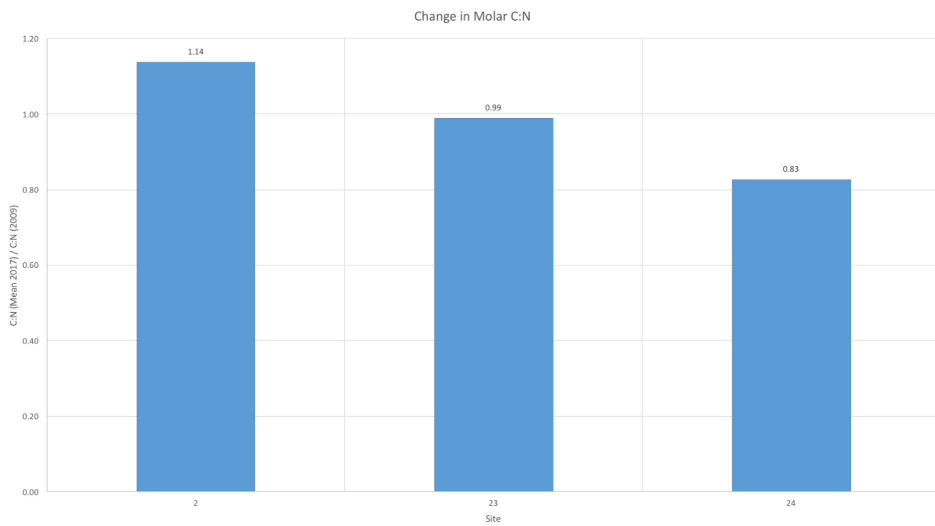


Figure 14. This shows the mean C:N values from Figure 9 divided by the mean C:N values from Figure 11. Sites plotted include those outside of the fire perimeter in Figure 1 with GPS error less than 15 meters and excluding sites with high standard diviation from the C:N

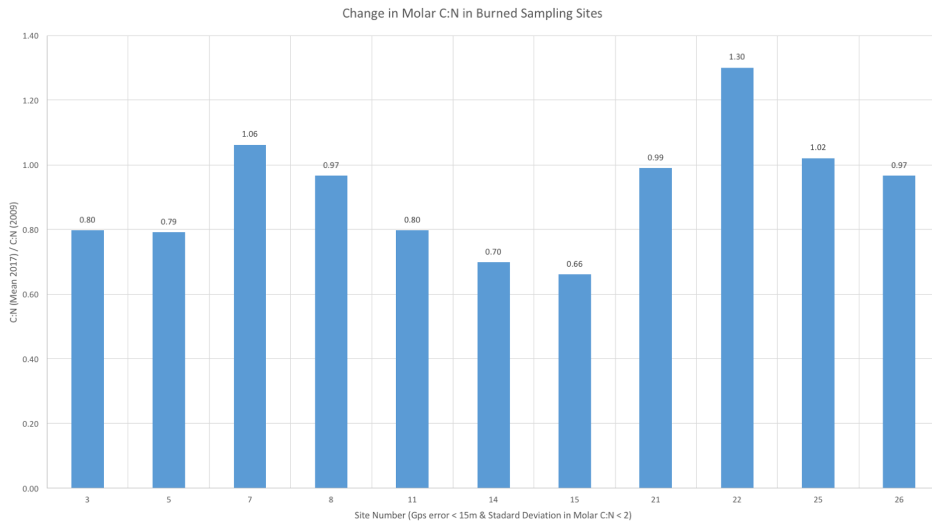


FIGURE 15. This shows the mean C:N values from Figure 9 divided by the mean C:N values from Figure 11. Sites plotted include those inside the fire perimeter in Figure 1 with GPS error less than 15 meters and excluding sites with high standard diviation from the C:N


FIGURE 16. This figure consists of the robust data for samples with surface area percentage dominated by grains with diameters in the 38-106$\mu M$ range. Surface area percentages and organic matter wt% by grain diameter from samples are plotted, along with changes in molar C:N. Note that grains in the 180-2000$\mu M$ are present, but do not make up a significant fraction of the sample at sites 21 and 26.

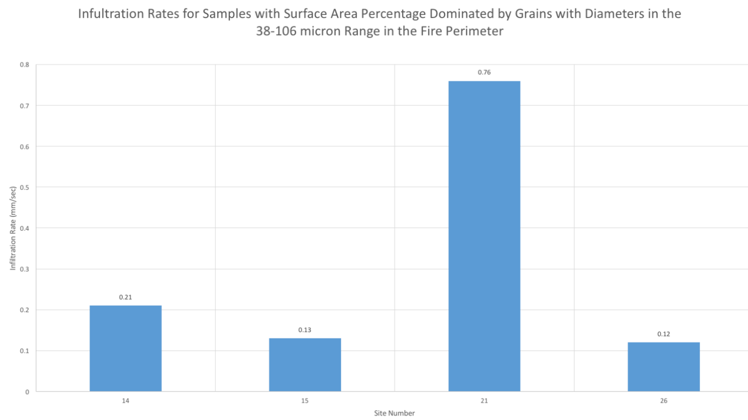


Figure 17. Infiltration Rates for Sites in the fire perimeter with surface area percentage dominated by grains with diameters in the 38-106$\mu M$ range.


FIGURE 18. Surface area percentages and organic matter wt% by grain diameter samples from samples collected at site 5 and site 25 are plotted along with changes in molar C:N are also plotted in this figure.

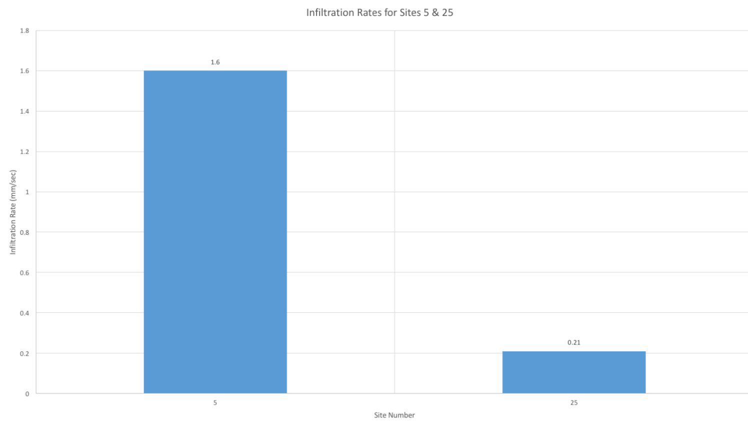


FIGURE 19. Infiltration Rates for Sites 5 and 25


FIGURE 20. This figure consists of the robust data for samples with surface area percentage dominated by grains with diameters in the 180-2000$\mu M$ range. Surface area percentages and organic matter wt% by grain diameter from samples are plotted, along with changes in molar C:N.


FIGURE 21. This figure consists of the robust data for samples collected outside of the fire perimeter. Surface area percentages and organic matter wt% by grain diameter from samples are plotted, along with changes in molar C:N.

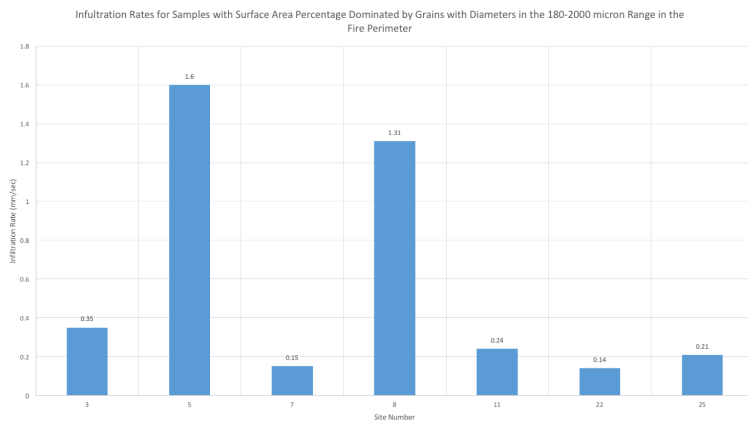


FIGURE 22. Infiltration Rates for Sites in the fire perimeter with surface area percentage dominated by grains with diameters in the 180-2000$\mu M$ range.

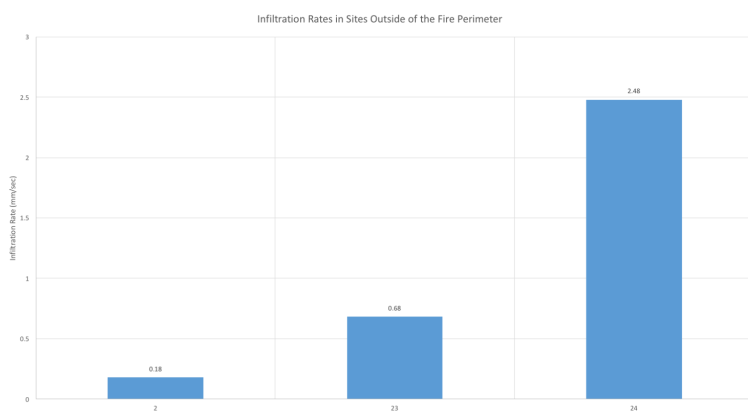


FIGURE 23. Infiltration Rates at sites collected outside of the fire perimeter

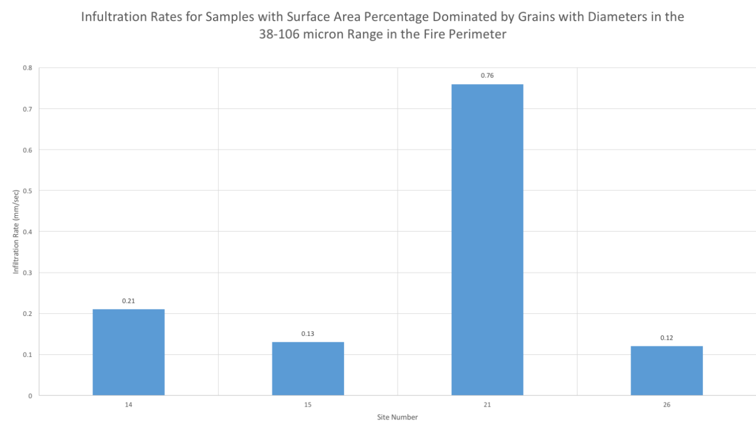


FIGURE 24. Infiltration Rates for Sites in the fire perimeter with surface area percentage dominated by grains with diameters in the 38-106$\mu M$ range.