VAST 2019 Report 4

Vivek Koodli Udupa
Madhumita Krishnan

August 30, 2019

1 The Scenario

St. Himark is a vibrant community located in the Oceanus Sea. Home to the world-renowned St. Himark Museum, beautiful beaches, and the Wilson Forest Nature Preserve, St. Himark is one of the region's best cities for raising a family and provides employment across a number of industries including the Always Safe Nuclear Power Plant. Well, all that was true before the disastrous earthquake that hits the area during the course of this year's challenge. Mayor Jordan, city officials, and emergency services are overwhelmed and are desperate for assistance in understanding the true situation on the ground and how best to deploy the limited resources available to this relatively small community.

In a prescient move, the city of St. Himark released a new damage reporting mobile application shortly before the earthquake. This app allows citizens to provide more timely information to the city to help them understand damage and prioritize their response. This report concentrates on using app responses in conjunction with shake maps of the earthquake strength to identify areas of concern and advise emergency planners on improving their rescue response.

2 Finding our standpoint: Figuring out the time of earthquake

Before diving deep into analyzing the affects of the earthquake, it is necessary to have an idea of when the earthquake hit the city and the amount of time that has elapsed before we are given the data for analysis. This helps us establish one of the following types of emergency response that could be improvised.

1. If the analysis is conducted immediately after the earthquake the priority would be helping the injured and reducing casualties.

2. If the analysis is conducted after a while, then the issues at hand would be in the vicinity of reconstruction of the city.

Figure 1 and Figure 2 show the effect the earthquake had on St. Himark. It is clear from Figure 2 that St. Himark was hit by the disastrous earthquake on April 8, 2020. This does give a better perspective of the time-line of the disaster but it does not help verify the type of emergency response to be considered for improvement.

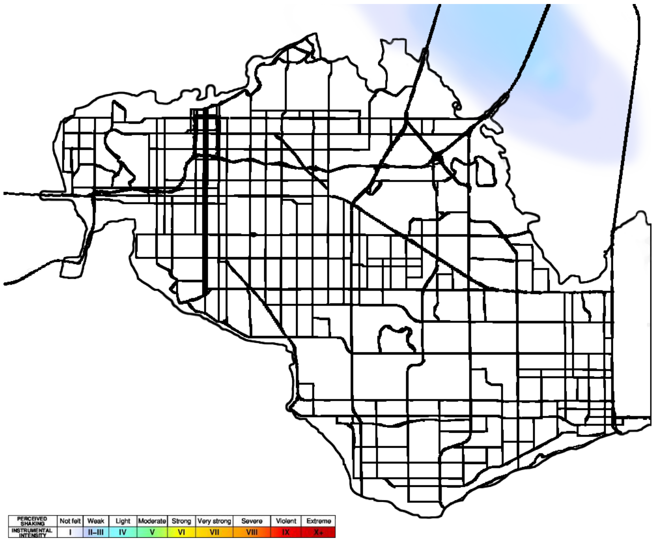


Figure 1: Shakemap as recorded on April 6, 2020

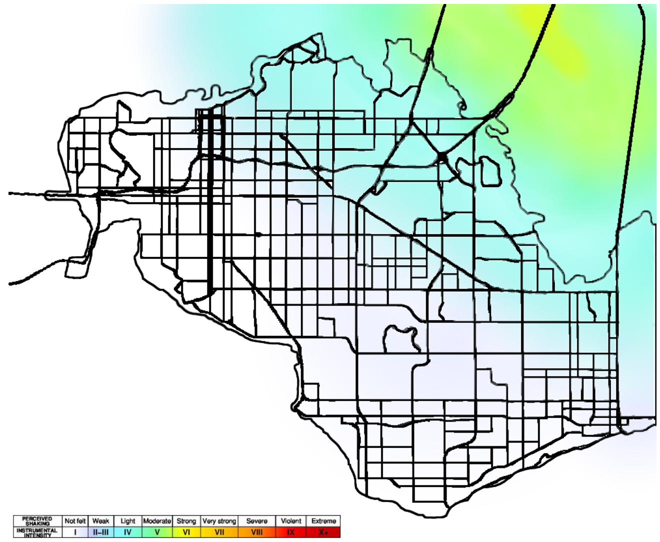


Figure 2: Shakemap as recorded on April 8, 2020

Plotting the entire range of shake intensities reported by the citizens will help determine the last received data. Figure 3 visualizes the same. It shows the number of damage reports recorded from April 6 - April 11, 2020. 6 damage reports were recorded on April 11. With this, it can be assumed that the analysis is done after the 11^{th} of April, 3 days after the impact. In 3 days, the emergency responders would have dealt with the fatally injured. The task at hand would be mainly scouting for more injured, relocating the affected victims and reconstruction of the cities.

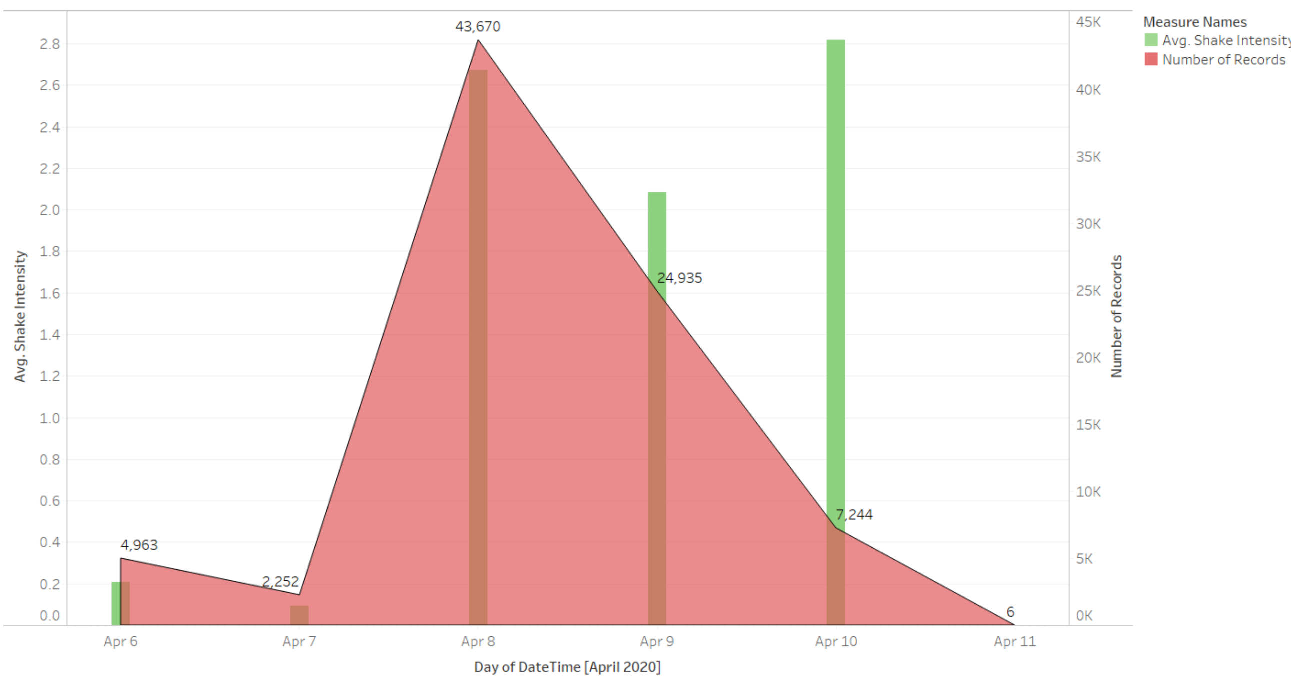


Figure 3: Recorded Shake intensities over the entire span of available time

3 Improving emergency response: Finding out the cities that were hit the hardest

Having a better idea of task at hand, the next step is to analyze the damage sustained by different cities.

Figure 4 shows the levels of shake experienced at different locations at St. Himark. The overall average Shake intensity felt throughout the entire region is approximately 2, which is not devastatingly bad. Locations 3, 4, 7 and 12 have felt shake intensities that averages above 4. Looking back at Figure 2, these locations are in direct impact zone of the earthquake. Thus the damages at these cities is probably higher compared to the rest.

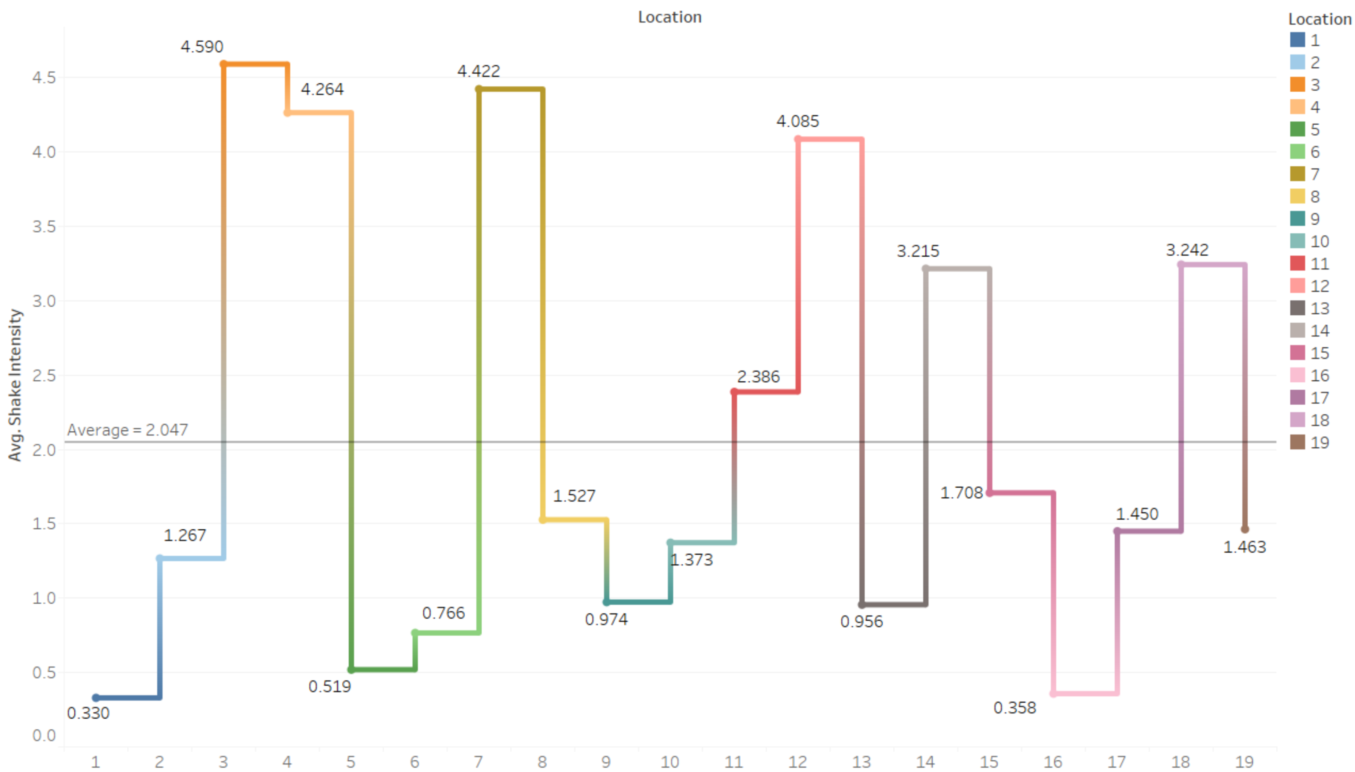


Figure 4: Shake intensities experienced by different locations

Figure 5 shows the average damage sustained by different cities. The represented damage is the sum of the average damage of different categories. Effectively it represents the reported overall average damage for different cities. The cities are sorted in descending order of total damage.

As expected, Location 3 has sustained the highest damage. It has sustained a total average damage of over 35 out of 50. But as for other locations, the damages are not proportional to the shake intensities recorded.

Location 9, which holds the second place for the most damaged cities, is mysterious. The shake intensity felt at this location is extremely low (0.974). (Refer Figure 4).

Location 4, which was expected to come second, has 10 cities with higher recorded damaged behind it.

One obvious reason for such a perplexing result would be the medical damages. Not all cities have hospitals. Thus the reported Medical damage at these cities would be zero. This effects the overall damage calculations. Location 9 has a hospital as opposed to Location 4 which makes the overall reported damage at Location 9 shoot higher than Location 4. Thus the metrics used to calculate the overall damage as shown in Figure 5 is not accurate enough to draw conclusions on which cities are hit the hardest.

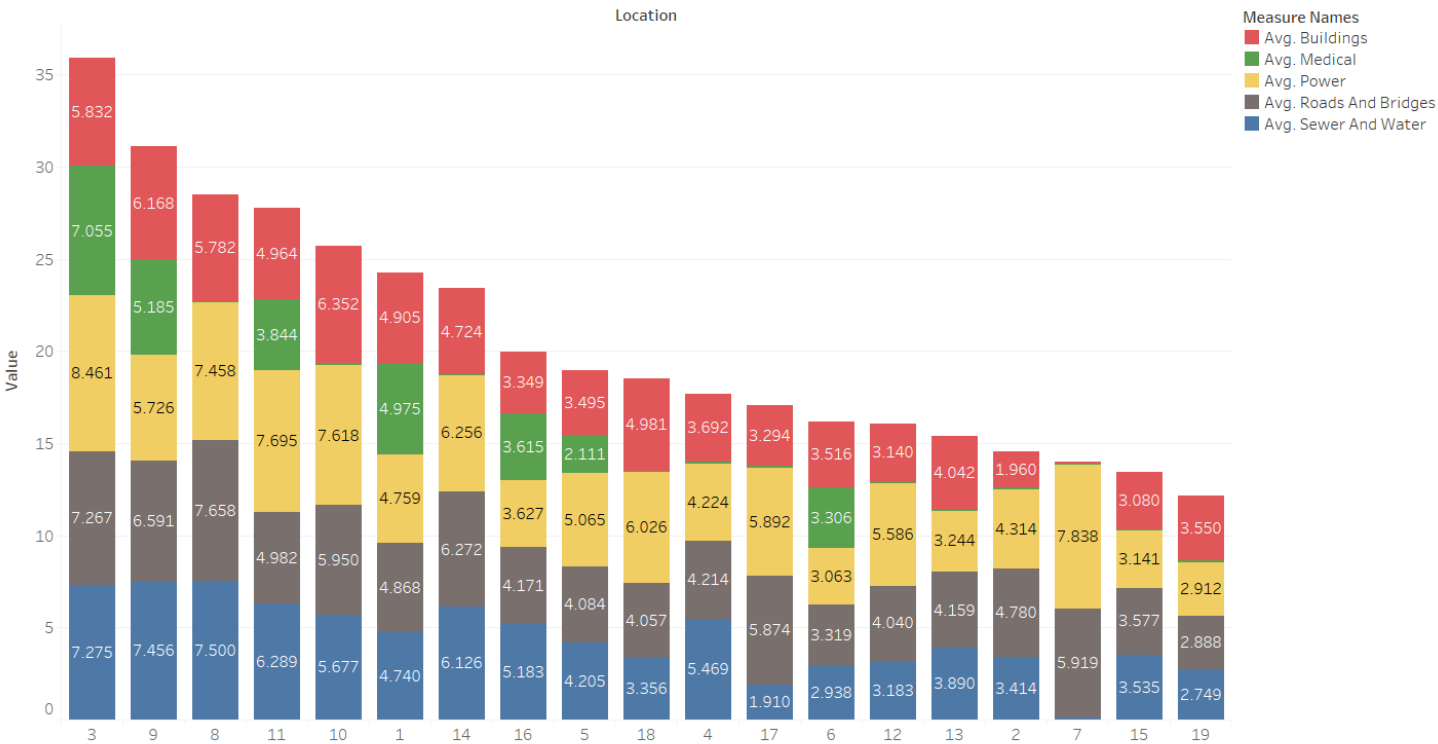


Figure 5: Average damage sustained by different cities (sorted)

It would be better to look at damages individually and act separately to counter the damages. The damage reporting app, RUMBLE, records 5 categories of damages.

1. Buildings
2. Medical
3. Roads and Bridges
4. Sewer and Water
5. Power

Buildings are the primary victims of earthquakes. A powerful enough earthquake can cause buildings to collapse, trapping people under the rubble. It is important to deploy search and rescue missions as soon as possible to help such victims.

Figure 6 shows the average damage buildings have sustained in different locations. The overall damage averages to approximately 4. 50% of the locations have sustained above average damage where Locations 10, 9, 3 and 8 require immediate assistance.

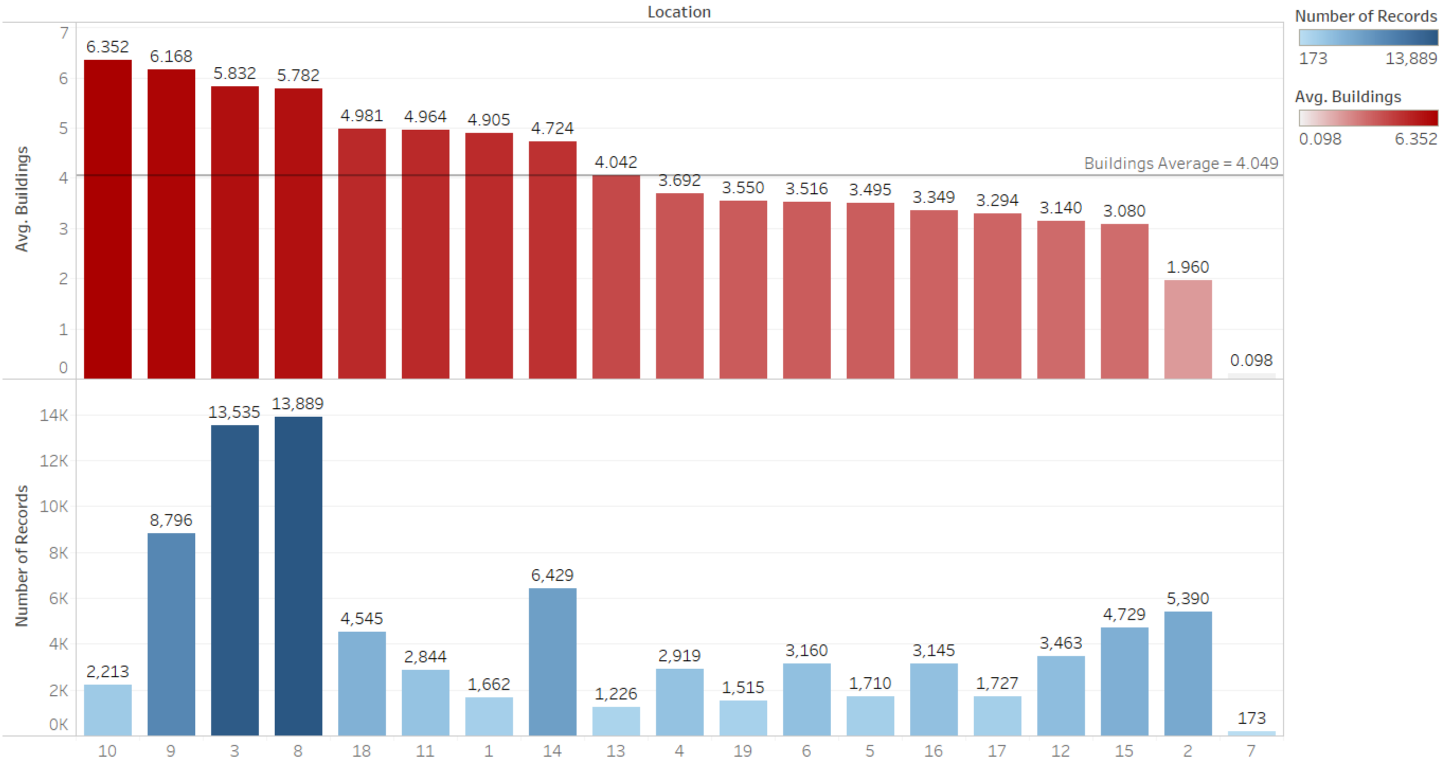


Figure 6: Average Building damage and number of damage reports recorded for all locations

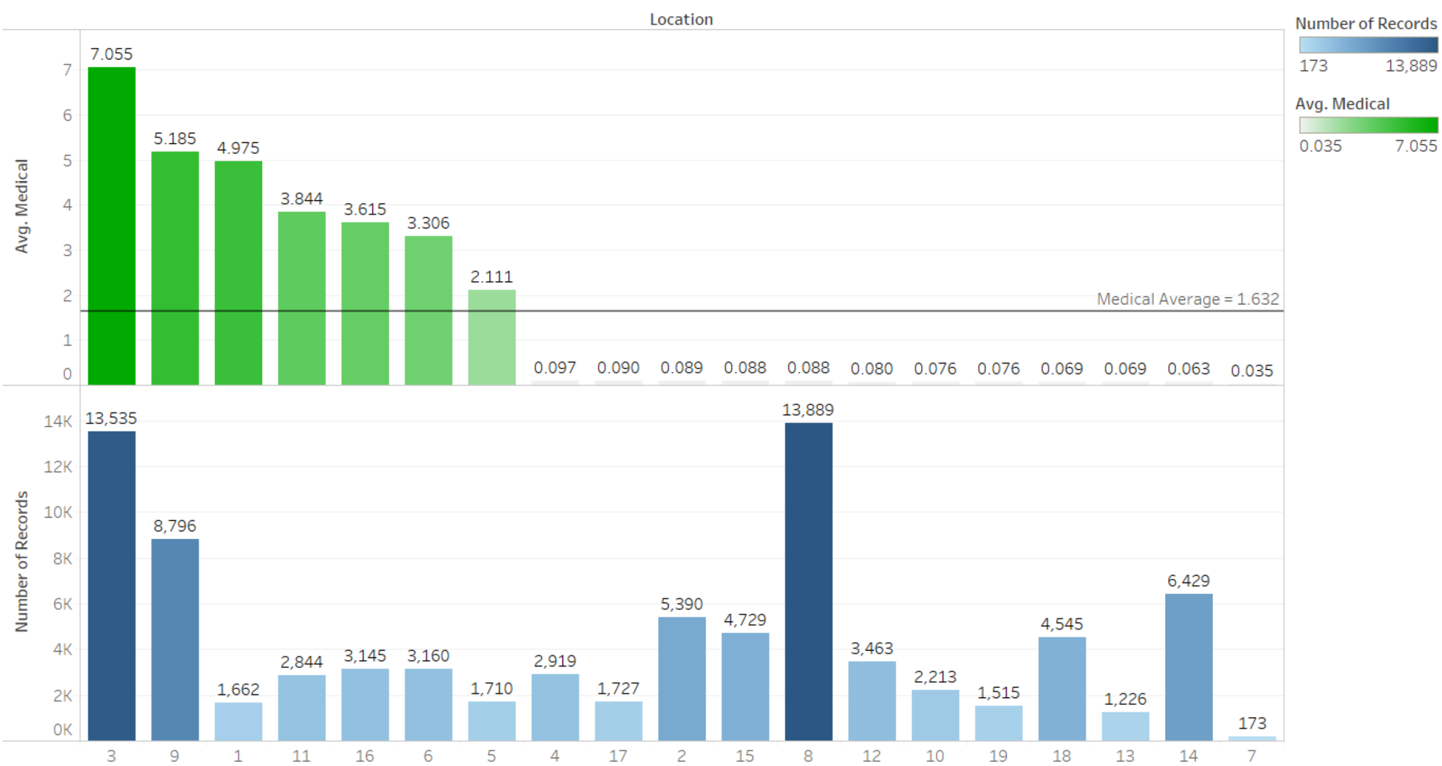


Figure 7: Average medical damage alongside number of recorded responses for all locations

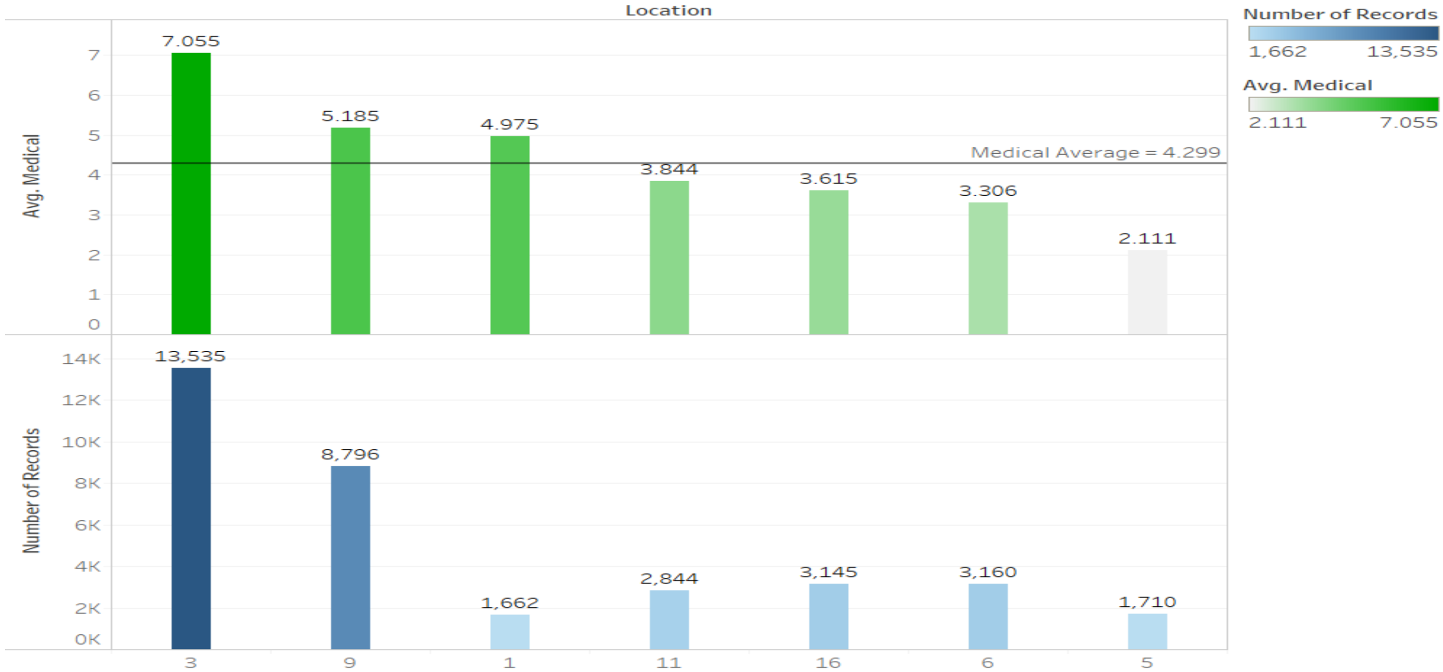


Figure 8: Location Filtered medical damage

Figure 7 represents the Average Medical damage and the corresponding number of reports for all the locations in St. Himark. The overall damage averages to a low 1.6. On further observation it can be seen that most locations do not have hospitals located in them and therefore have no medical damage reports.

Figure 8 shows a more accurate visualization of medical damage because only locations with hospitals are considered. The average medical damage changes from a low of 1.6 to 4.3. Locations 3, 9 and 1 have damage values more than the average. Location 3 can be seen to have the highest damage value.

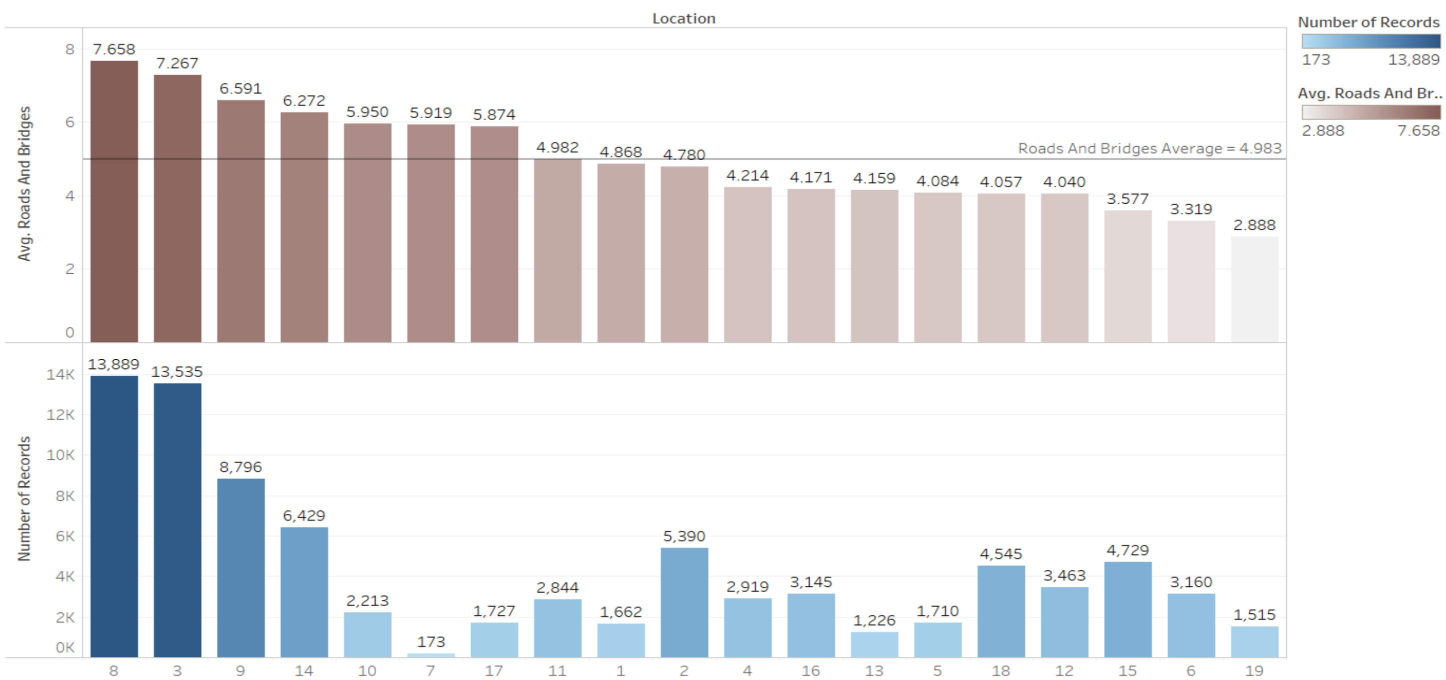


Figure 9: Average Road damage and number of damage reports recorded for all locations

Figure 9 visualizes the average damages sustained by the roads of St. Himark. The overall damage averages at 4.9. 7 locations have damages higher than the overall average. Locations 8 and 3 have the highest road damage reports as well as the average road damage.

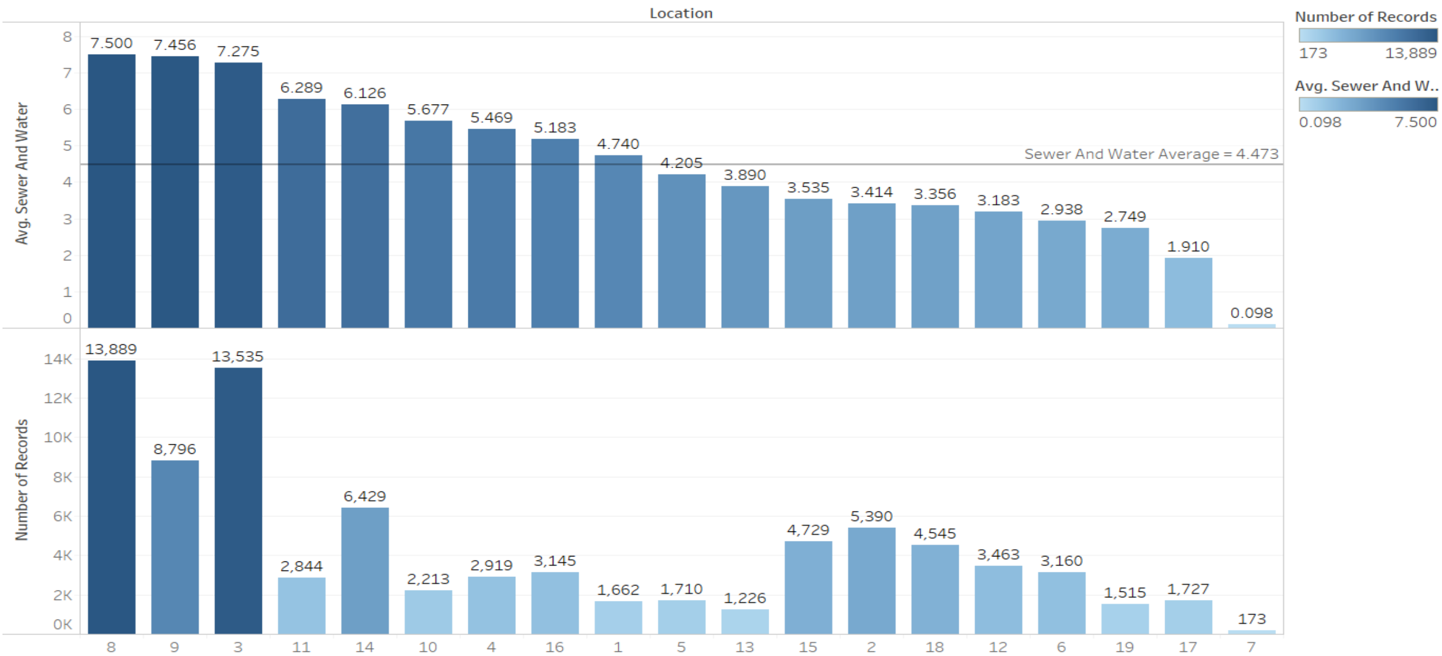


Figure 10: Average Water damage and number of damage reports recorded for all locations

Figure 10 displays the average water damages in different locations. The overall sewer and water damage average is found to be 4.473. 9 of 19 locations have reported damages higher than the overall average. Locations 8, 9 and 3 have been affected the most.

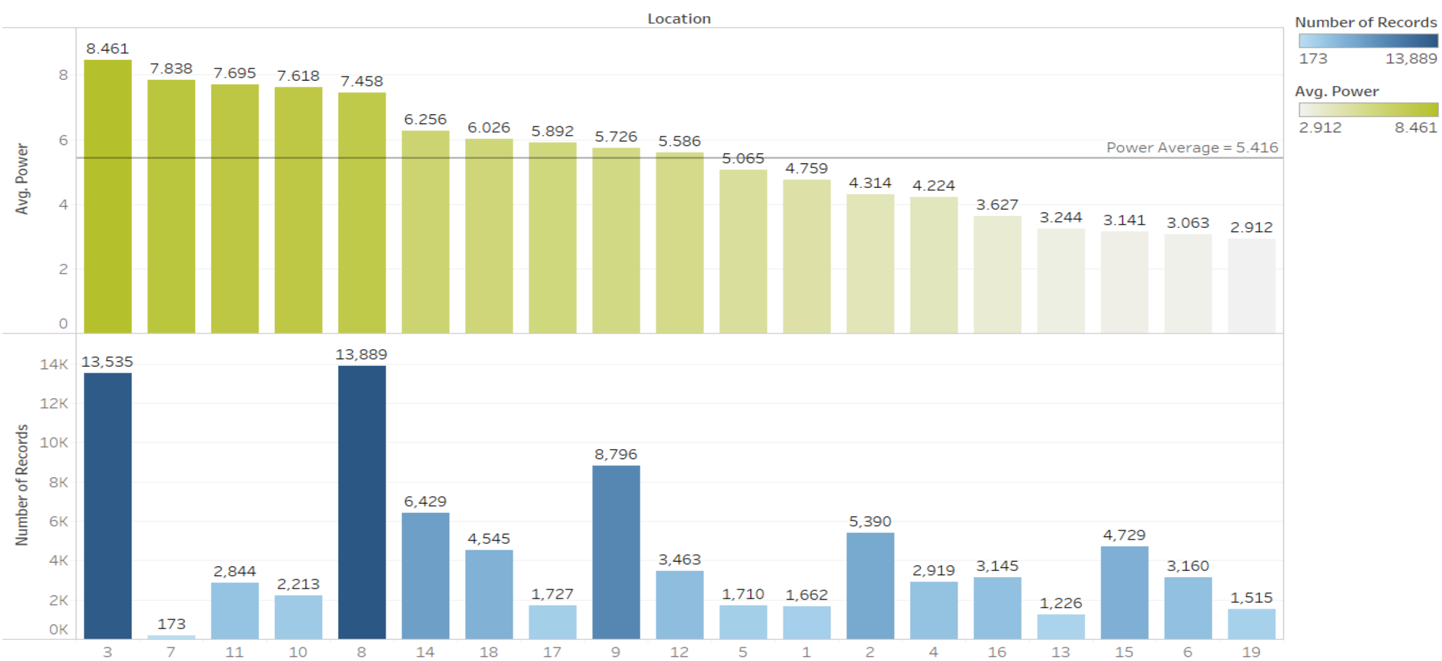


Figure 11: Average Power damage and number of damage reports recorded for all locations

The power damages for all locations can be seen in Figure 11. Location 3 has sustained the highest power damage.

4 Questioning the source: Measuring the uncertainty in the recorded data and Comparing the neighborhood for reliable damage reports

This section of the report will dive deeper into the dataset and try to find a rationale to explain the results seen in section 3.

Figure 6 visualized that locations 10, 9, 3 and 8 were hit the hardest. How reliable are the damage reports from these locations? Let us look at the distribution of the damage reports shown in Figure 12.

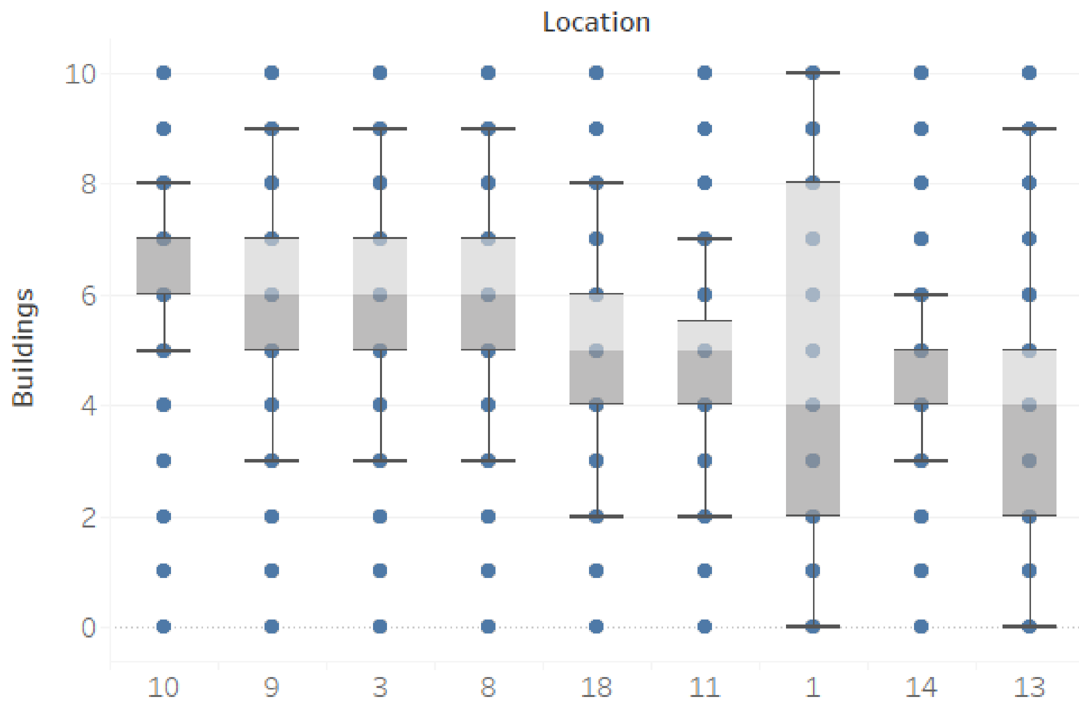


Figure 12: Variance in Building Damages

On a general note, a box plot that is spread out conveys a message that the damage reports are varying a lot and a compact box plot shows that the damage reports from different sources agree on a particular value.

Looking at Figure 12 it can be easily noted that Location 1 has damage reports varying from 0 to 10. The citizens of Location 1 has reported damages of all ranges. A Minimum building damage of zero and a maximum of ten has been recorded. Out of the total 1662 recorded damage reports, 831 (50%) reports shows a damage ranging from 0 to 4, while the remaining 831 citizens argue that the damage is above 4. The variance in the estimation of the damage seen by the residents of Location 1 is high. Narrowing down on the actual damage from such a spread out box plot is impossible. Thus the building damage reports from Location 1 are highly unreliable.

The reports from Locations 9, 3 and 8 tell a different story. The minimum reported damage is 3 and the maximum is 9. The spread is not high, but considerable. The rest of the damage values reported out of the 3 to 9 range can be considered as outliers. Half of the citizens of these locations agree that the damage between 3 and 6 while the rest perceive the damage to be above 6. This result raises suspicion. From Figure 2 and Figure 4 it can be seen that Locations 8 and 9 are far outside the earthquake shake zone, experiencing an average shake intensity of less than 1, whereas Location 3 takes the impact head-on with a recorded average shake intensity of 4.56 which is the highest compared to other locations.

In order to assess the reliability of the reports from Locations 8, 9 and 3, we will compare these results with another location, which seems definitive. Location 14, which is located between 3 and 9 works as a good reference point. Location 14 has a recorded average shake intensity of approximately 3 and is physically located between 3 and 9. Locations 8 and 9 are neighbors to each other. The distribution of the building damages reported at Location 14 is highly compact. 75% of of the population of Location 14 agrees that the damages are less than 5 and 50% agree that the damage is between 4 and 5. It is easy to draw a conclusion that the damage faced here is approximately 5. Based on this conclusion, Locations 8 and 9 reporting a damage greater than 5 appears to be unreliable.

This analysis, is however challenged by the damage reported at Location 10. Location 10, which appears in the vicinity of Location 8 and 9 has experienced a shake intensity of approximately 1.3, but shows the highest building damage reported among all other locations. Figure 6 shows the average building damage to be 6.35 and Figure 12 shows a very compact damage distribution, with 75% of the population reporting a damage between 5 and 7. Excluding location 10, all other cities towards the south eastern side of St. Himark (Locations 8, 9, 13, 12, 11) shows a spread out damage distribution. This makes it really difficult to conclude on the actual damage faced by these locations.

The reason for such ambiguous damage reports could be that there was no standard reference for the citizens to assess the damages. If the damage reporting app, RUMBLE provided certain reference point to judge the damage, the citizens might be able to produce more accurate damage reports.

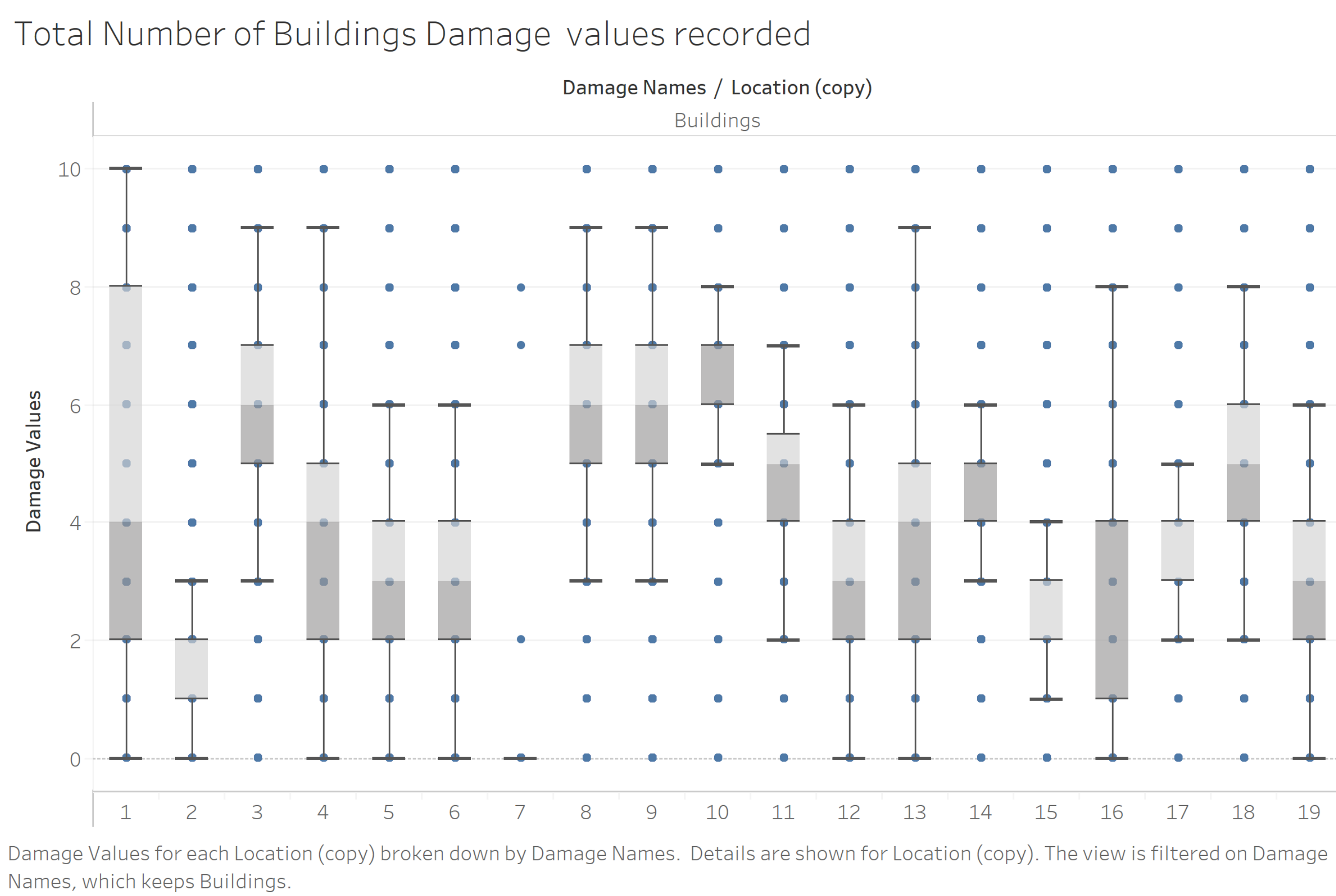


Figure 13: Distribution of reported building damage for all locations

St. Himark has a total of 7 medical facilities spread across the entire area. In this hour of disaster, Medical facilities play a important role in reducing the casualties. But unfortunately, hospitals too suffer damages from the earthquake which might effect the amount of patients each hospitals can take in. Figure 14 shows the distribution of the medical damage reported by the citizens.

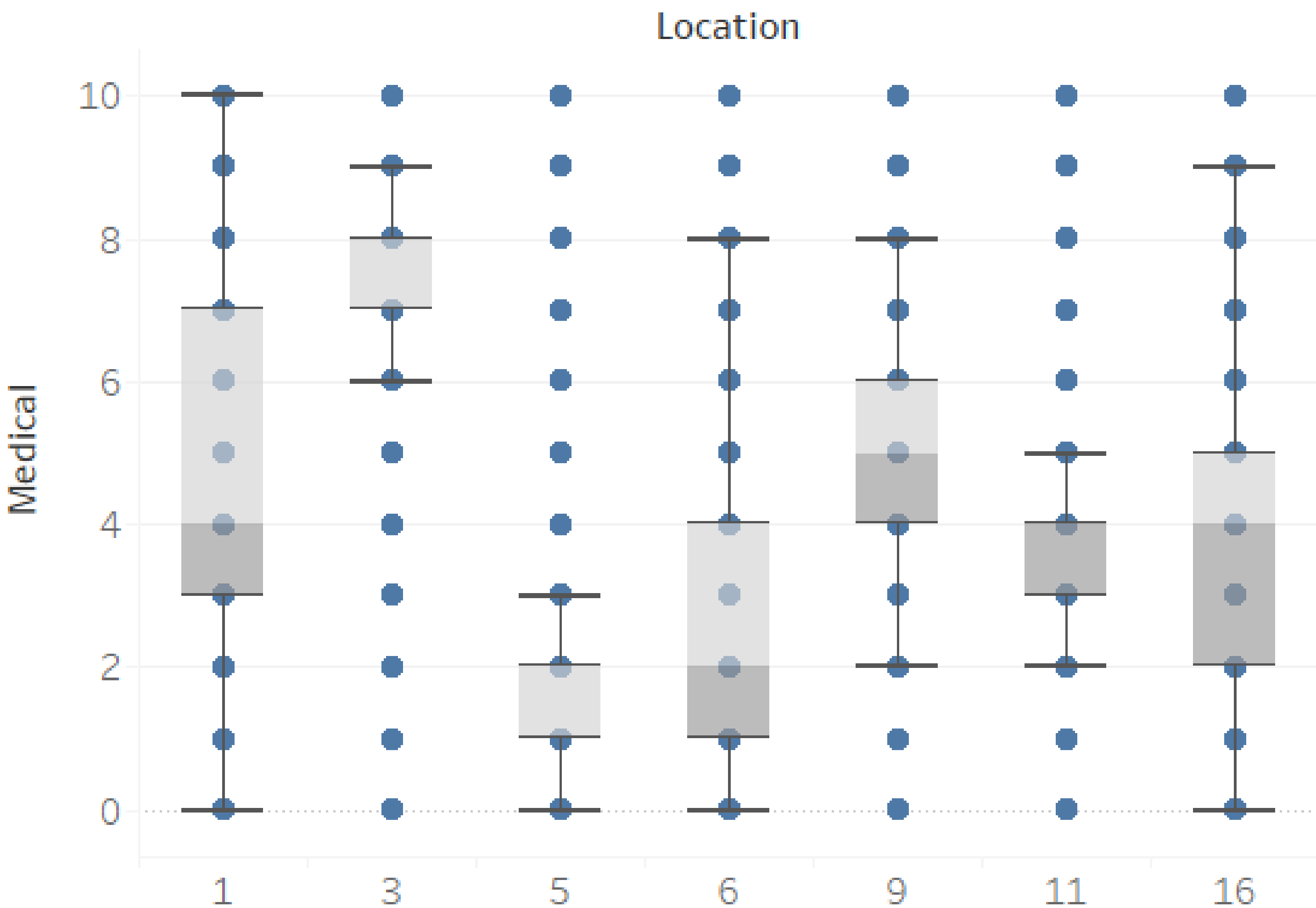


Figure 14: Variance in Medical Damages

As experienced with the building damages, citizens of Location 1 seem to have very vivid opinions about the damages that they see. The damage reports are spread out and narrowing down on the actual damage is an impossible task. The data from Location 1 continues to be highly unreliable.

Locations 3, 5 and 11 however as a very compact box plot. The damages reported at these locations seems very reliable as they do go along with the shake intensities experienced at these locations. Location 3 has a 75% vote on damages between 7 and 8, thus can be narrowed down to 7, which is the mean of the distribution. Similarly, medical damages at location 5 and 11 can be narrowed down to 1 and 4 respectively.

Locations 6, 9 and 16 has damage reports that are considerably spread out, thus assuming the worst, the damage could be assessed as the value at the third quartile.

The roads have taken a toll due to the disastrous earthquake. Having a clear idea of the road damages helps the emergency responders to arrive at the required locations as fast as possible. Knowing the routes that are inaccessibly damaged aids in finding alternate route before hand which helps in avoiding unnecessary detours which consume a lot of time. Figure 15 visualizes the distribution in the reported road damages helping to separate the reliable reports from the unreliable ones.

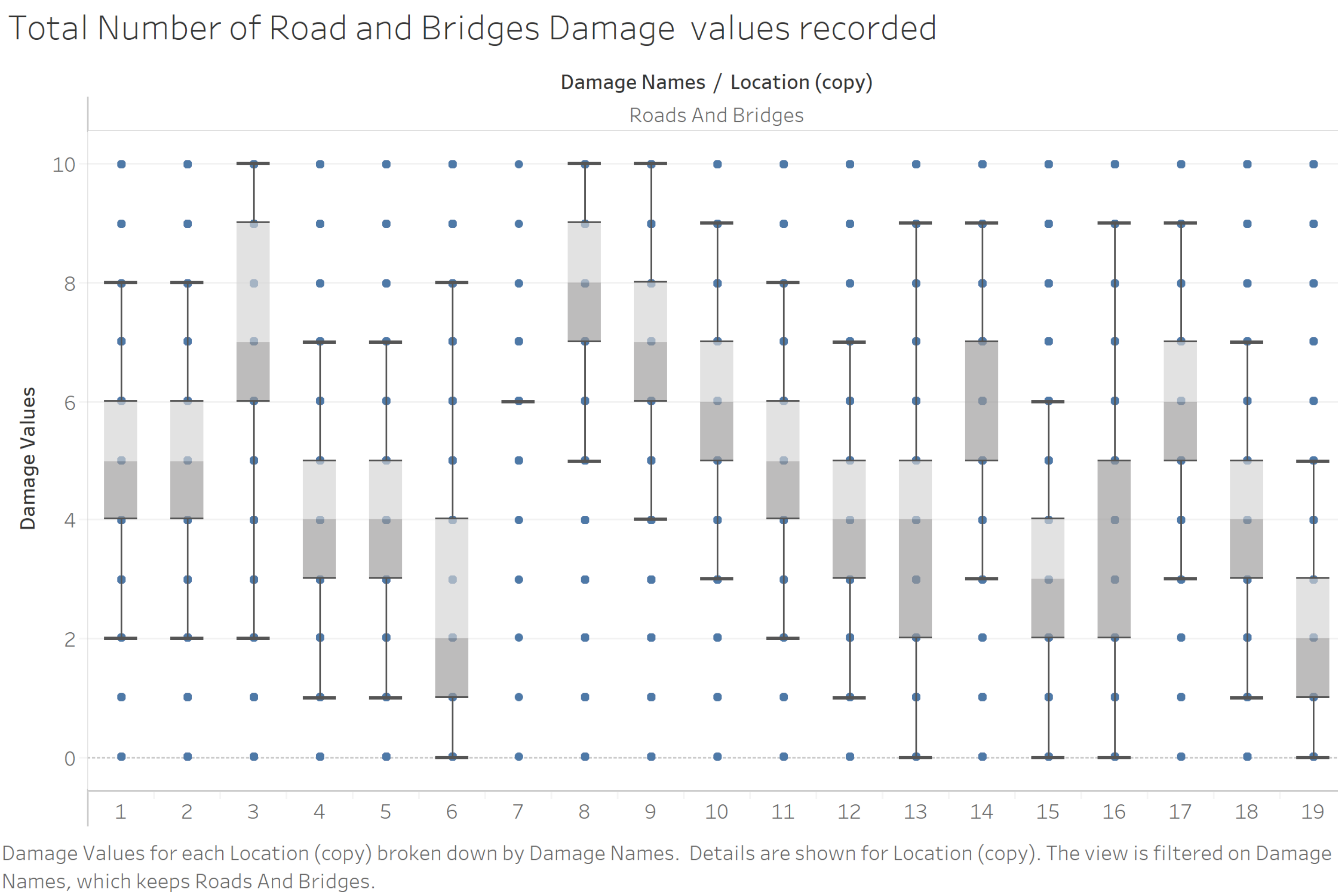


Figure 15: Variance in Road Damages

The roads and bridges damage reports are all spread out. The citizens seem to have a tough time judging the road damages. Location 7 is an exception. It has extremely compact distribution. But it might be because of the lack of reports coming in from that location. Only 173 reports have been recorded from Location 7.

This inconsistent damage assessment of roads might be because of the already ongoing road repairs. The controlled broken down / shut off roads might have caused confusion among the citizens resulting in irregular damage assessment.

Due to this inconsistency, it is difficult to draw a conclusion on specific roads to be avoided. As a precautionary measure, a higher ETA is to be taken into consideration while deploying emergency services.

Locations 3, 8 and 9 are to be considered for extra attention as they show high damage. The following roads are advised to be avoided as they were documented as "under repair" :

1. Wilson Highway – shoulder repair resulting in occasional traffic delays.

2. Broadview, Scenic Vista, and Southton neighborhoods – resurfacing of residential streets resulting in minimal delays to traffic.

3. Downtown neighborhood – resurfacing of collector roads, traffic signal repairs. Delays expected.

4. Chapparal and Cheddarford neighborhoods – resurfacing of collector roads. Expect delays.

5. Friday Bridge – guard rail repair. Expect some delays.

6. Magritte and Jade Bridges – repair of bridge decking. Lanes are restricted. Expect delays.

Water and Electricity are essential to survive. On top of having their homes damaged, having to deal with broken water and power outages could become challenging.

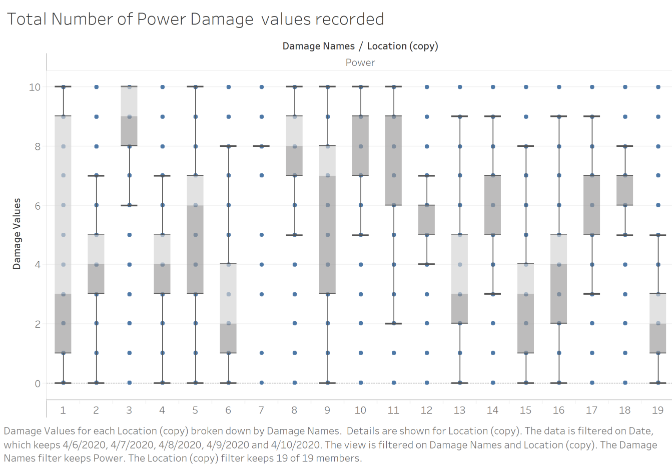


Figure 16: Reported Power Damages distribution

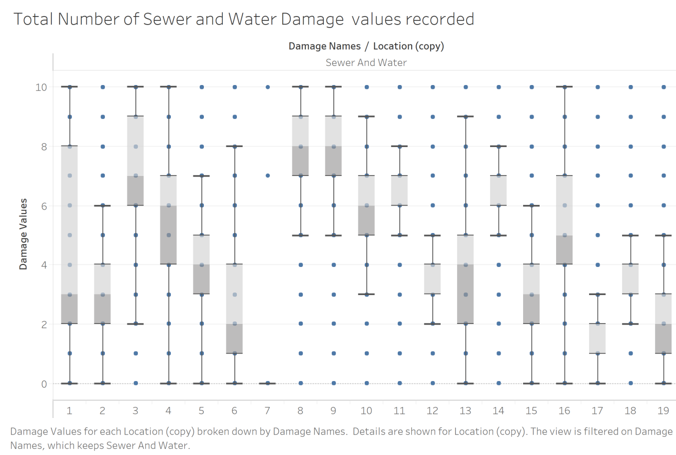


Figure 17: Reported Water Damage distribution

As visualized in Figure 16 Location 3, 8 and 10 suffer from high power damages. These areas need to be given special attention. Lack of power could hinder the ability to call for help.

Locations 12 and 18 with a reliable distribution, shows median power damage to be 6 and 7 respectively. This works as a reference point in assessing the damages in other cities.

Locations 1, 5 and 9 show extreme spread, thus falling under the unreliable category.

Figure 17 helps visualize water damage distribution. Locations 11, 12, 14 and 18 show compact distribution. However, Location 12 shows lower damage as compared to Location 11, which raises a suspicion because location 12 is hit directly by the earthquake, dealing with higher damage. Location 11 is primarily a farming area, thus using water more as compared to Location 12. Since the usage of water is more in Location 11, the effect of damage on citizens life could have been considerably higher. This however, is just a hypothesis and there are no sufficient data to prove it. Separating the commercial and domestic water source damages would probably help understand the situation better.

Locations 1, 4, 13 and 16 are extremely spread out, this highly unreliable.

5 Improving emergency response: Prioritizing the neighborhoods

All lives are weighed equally and it is ideal to help out everyone as soon as possible. But due to the current circumstances, the emergency service available is limited. Thus based on the conclusions drawn from Section 4, certain neighborhoods will be prioritized for emergency response.

Considering all the damages, Location 3 and Location 4 are hit the hardest and need some sort of medical help. Location 4, a.k.a. Safe Town houses a nuclear power plant. Extra care must be practiced while dealing with this locations in order to prevent the spread of radioactive damage. Location 3 has sustained heavy medical damage. Thus it is ideal to avoid using Location 3's hospitals to treat victims that need immediate care. They can be redirected to Location 6, which houses 2 hospitals and is in the vicinity of Location 3. The injured from Location 4 must be split up and taken to Locations 16 and Location 11, whichever is closer at the given time instance.

Locations 8, 9 and 10 are to be prioritized next. Due to unknown circumstances, these locations how abnormally high damage. It is advised to send a small team before hand to assess the damage better.

While transporting the injured from Location 4 to Location 16, it is recommended to take the 12th street via Location 15, as this location has sustained considerable less damage. Location 10 is to be avoided while travelling from Location 4 to either Location 9 or 11.

Overall, The North-Eastern part of St. Himark needs to be prioritized first as these locations have taken the earthquakes impact head on. South Eastern part has taken heavy damage due to unknown causes, thus this region is to be avoided unless necessary. The Western section of St. Himark remains relatively unharmed, thus re-routeing all necessary emergencies to these locations is ideal. Location 1 however shows highly unreliable damage reports, thus it needs to be assessed separately by experts to accurately understand the situation.

6 The Aftermath: How does the conditions of St. Himark change over time?

6.1 Possibility of a Second Earthquake

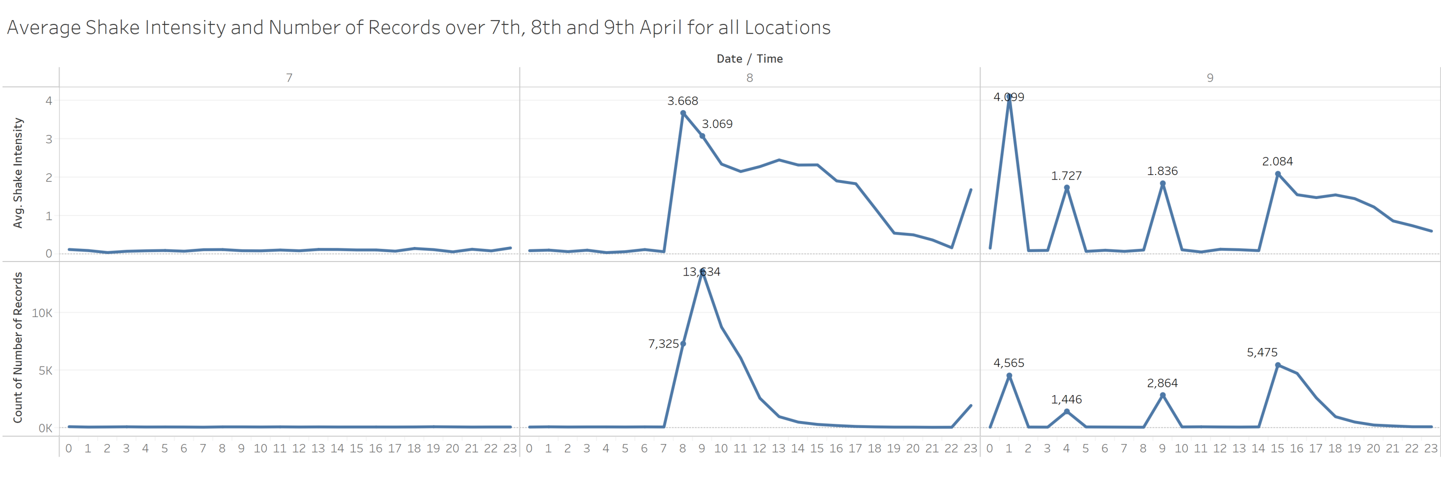


Figure 18: Average Shake Intensity and Number of Records over time for all Locations

Figure 18 displays the variation in the average shake intensity and number of reports over 7^{th}, 8^{th} and 9^{th} of April in all the locations. On observing the figure intently, it can be seen that the first earthquake takes place on 8^{th} April. Furthermore there are four distinct peaks on the 9^{th} of April. The first three of these peaks represent the damages that were reported on the 8^{th}, due to power cuts these reports have reached the server late. This will be discussed in detail in Section 6.2. The fourth peak on 9^{th} that occurs between 2:00 pm to 5:00 pm most probably represents a second earthquake that occured in St.Himark. This information, the number of earth quakes, has not been provided in the data source and there is not sufficient data to predict its actual time of occurrence.

6.2 Power Outages in St.Himark

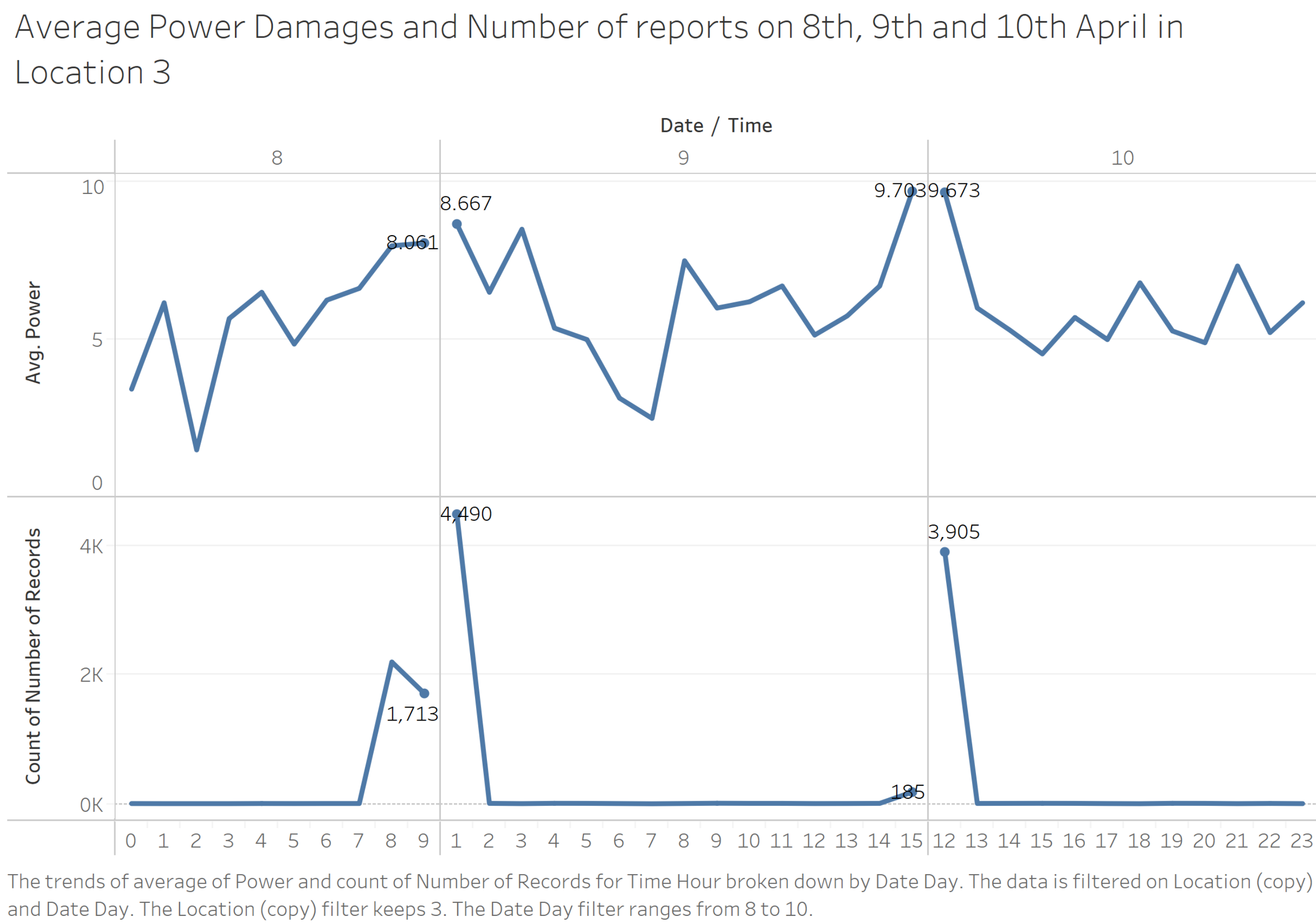
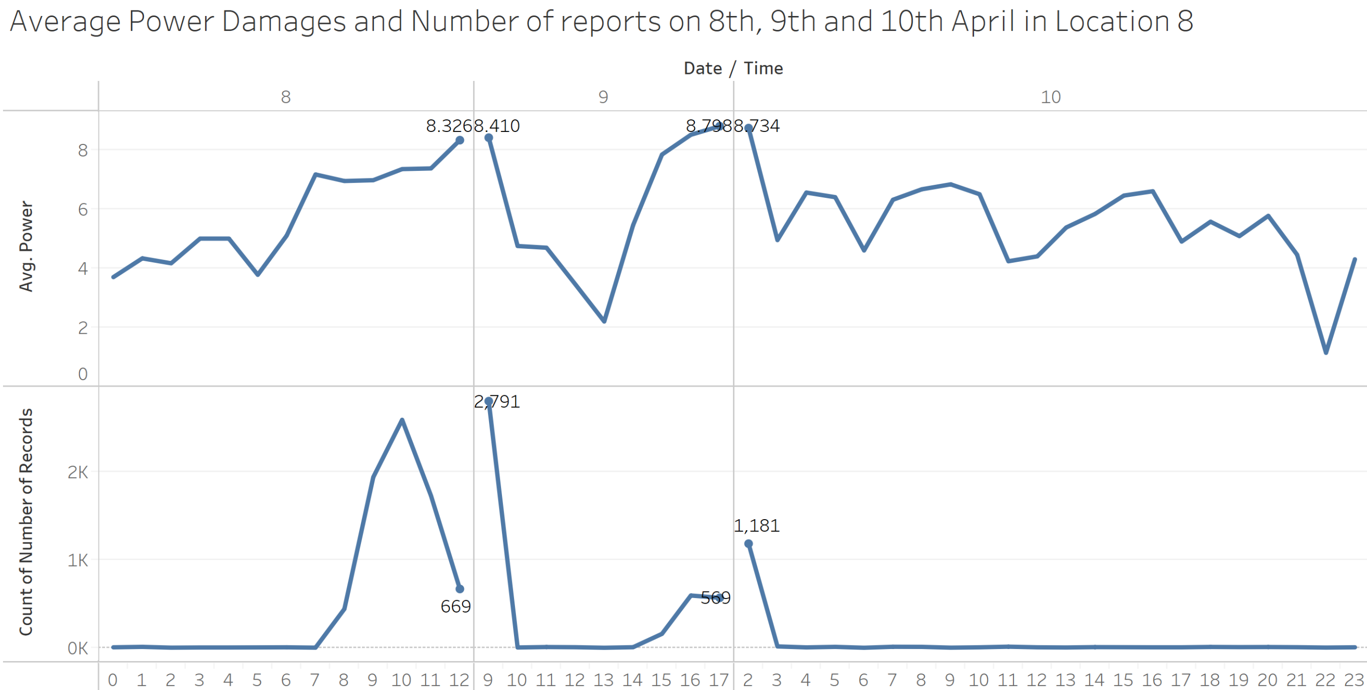


Figure 19: Average Power Damage and Number of Records over time for Location 3

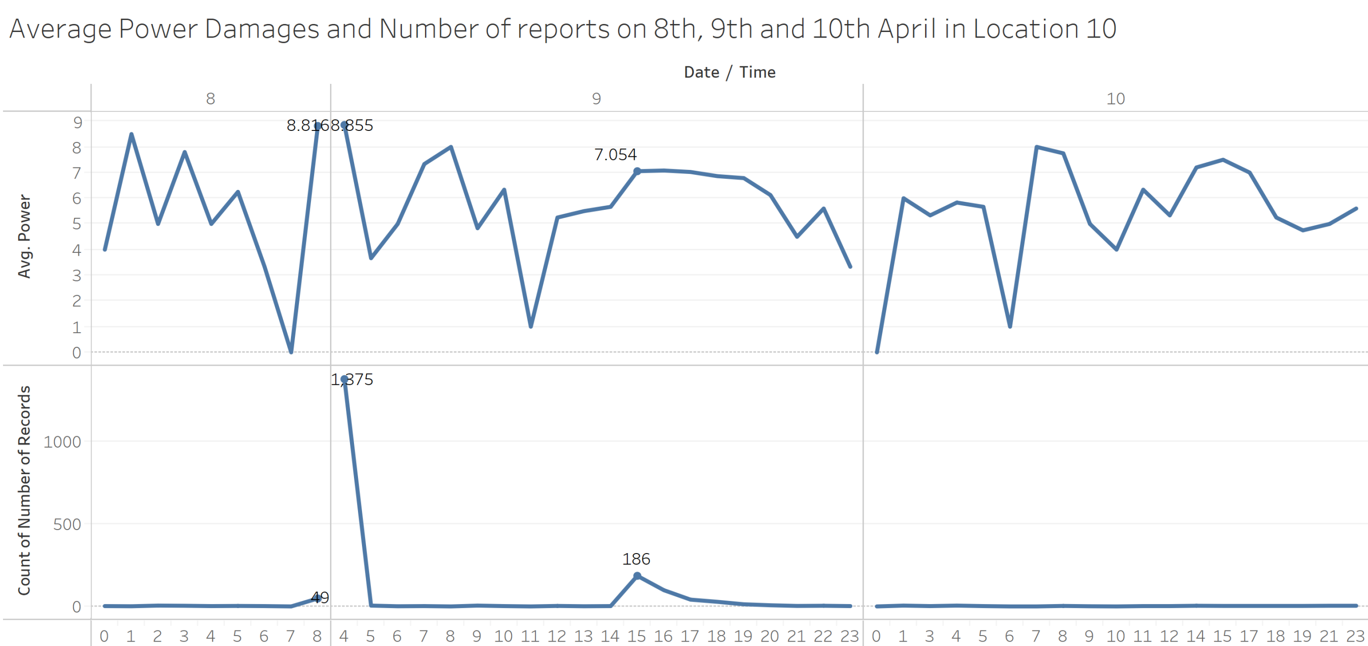
Figure 18 displays three peaks on April 9^{th} that represent excessive number of reports which accumulated in the server due to a power outage. The above conclusion was made by observing the power damages in different locations. Figure 19 represents the average power damage and number of reports over 8^{th}, 9^{th} and 10^{th} in Locations 3. According to this figure the first power cut occurs around 9:00am on April 8^{th}. This leads to a spike in number of reports and power damage at 1:00am on April 9^{th} . It explains the first peak in Figure 18 which occurs on April 9^{th}. Further Figure 19 shows another outage can be seen at 3:00pm on April 9^{th}. This was the time around which a second earthquake was assumed to have taken place in Section 6.1.



The trends of average of Power and count of Number of Records for Time Hour broken down by Date Day. The data is filtered on Location (copy) and Date Day. The Location (copy) filter keeps 8. The Date Day filter ranges from 8 to 10.

Figure 20: Average Power Damage and Number of Records over time for Location 8

Figure 20 displays the average power damage and number of reports recorded in Location 8 over the period between 8^{th} to 10^{th} of April. A power cut can be seen around 8:00am on April 8^{th} which is around the time of the first earthquake. This results in a rise in the power damage and the number of records on 9^{th} April which results in the third peak in Figure 18 at 9:00am. A second power outage occurs in Location 8 around 5:00pm on the same day which might be a result of another earthquake.



The trends of average of Power and count of Number of Records for Time Hour broken down by Date Day. The data is filtered on Location (copy) and Date Day. The Location (copy) filter keeps 10. The Date Day filter ranges from 8 to 10.

Figure 21: Average Power Damage and Number of Records over time for Location 10

The variation in average power damage and number of reports over time for Location 10 can be seen in Figure 21. It can be seen from observing the figure that there are no records after 8:00am which is the result of a power outage at Location 10 while the value of power damage seems to be increasing right before the outage on April 8^{th} . An increased damage and number of records is observed on the 9^{th}. This is the cause for the second peak in Figure 18 at 4:00am.

7 Appendix

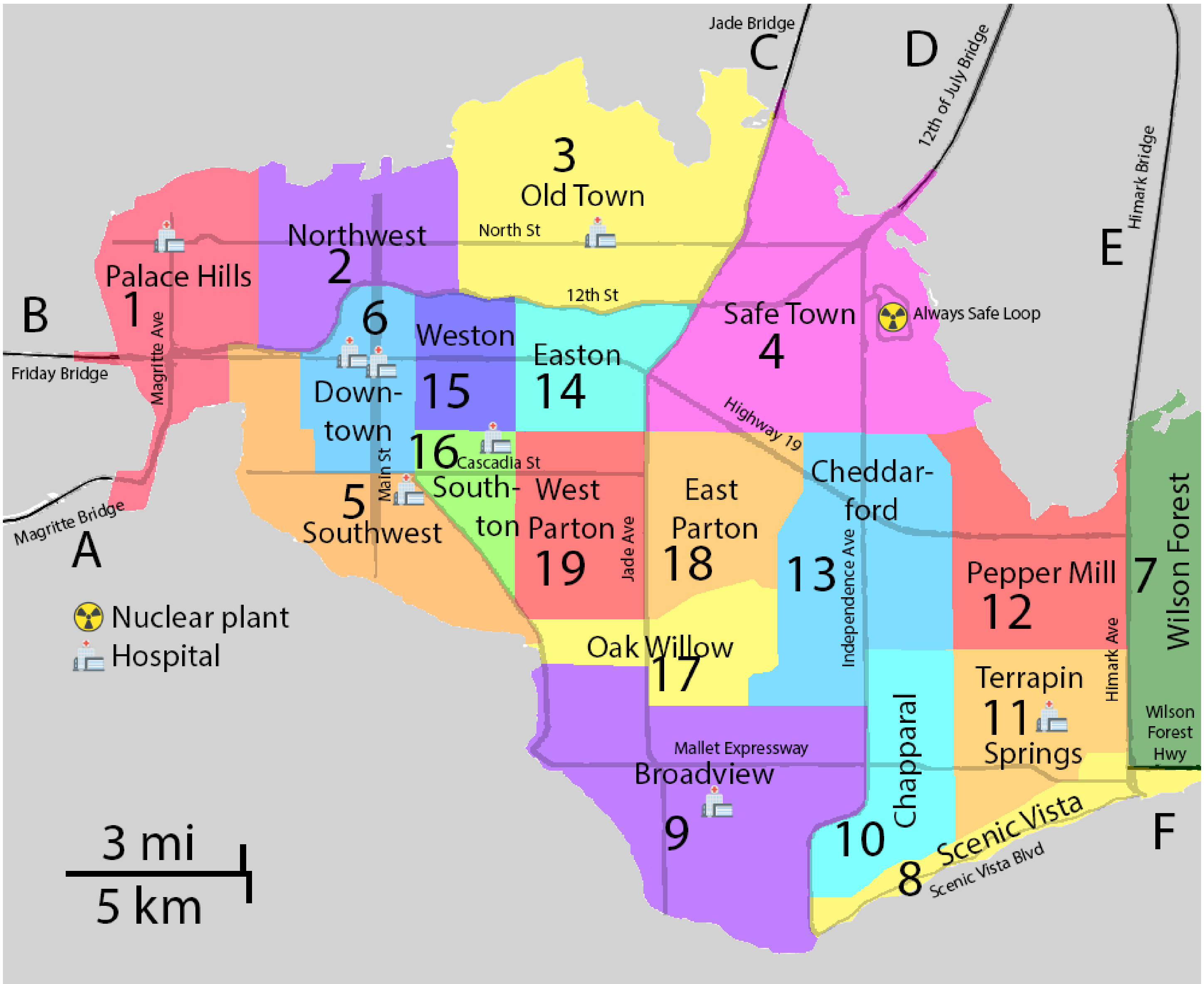


Figure 22: Map of St. Himark highlighting the cities with the corresponding location codes

8 Reference

[1] VAST 2019 - St. Himark - About our City.docx