Seismic Detonation and Residential Damage: Assessing Mining Impact in Naples, Florida

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ABSTRACT

Mining activities, particularly controlled blasting, generate seismic vibrations that may impact nearby residential structures. This study examines whether ground vibrations from the 846 Mine in Naples, Florida, contribute to reported structural damage in Golden Gate Estates. Seismic data recorded from January to October 2024 were analyzed using a GeoSonics, Inc. Remote Seismograph System, which measured Peak Particle Velocity (PPV) and air overpressure at monitored locations. A total of 7 blast events were documented across three residential properties. On-site inspections of the affected homes provided structural assessments. Results indicate that recorded PPV levels ranged from 0.02 in/sec to 0.065 in/sec, well below the U.S. Bureau of Mines' threshold of 0.5 in/sec for cosmetic damage. The highest recorded air overpressure level was 108 dB, which remains within the 133 dB safe limit. Although Property C exhibited the highest PPV, all values remained within regulatory guidelines. While no definitive causal link was established, localized factors such as variations in soil composition, structural differences, and pre-existing conditions may influence observed damage reports. Findings suggest current regulatory thresholds may not fully account for localized vulnerabilities, emphasizing the need for revised standards that consider soil variability and cumulative vibration effects. Additionally, implementing stricter blast monitoring requirements and mitigation strategies, such as limiting charge weights near residential areas, may enhance structural protection. Future research should focus on long-term monitoring, larger sample sizes, and advanced modeling to better assess site-specific risk factors.

IMPACT STATEMENT

This research has the potential to significantly influence both the mining industry and residential communities by providing empirical data on the effects of mining-induced seismic vibrations on nearby structures. By establishing whether a direct correlation exists between blasting vibrations from the 846 Mine and the reported damage in Golden Gate Estates, the study could lead to the implementation of stricter regulatory measures for mining operations near residential areas. Such findings would enhance the safety and protection of homeowners, particularly in areas where industrial and residential developments coexist. Furthermore, this research may offer valuable insights into the long-term effects of repeated seismic exposure, guiding future mitigation strategies and informing construction practices in vulnerable regions. The study's findings could also serve as a model for similar investigations in other mining areas, contributing to a broader understanding of the complex interactions between industrial activities and residential infrastructure.

1.0 INTRODUCTION

Mining activities, particularly blasting operations, are a cornerstone of resource extraction, providing essential materials for industrial and economic development. However, these activities generate significant ground vibrations that can impact adjacent residential areas. In regions like Golden Gate Estates in Naples, Florida, where mining operations are in close proximity to housing, the consequences of seismic activity extend beyond geological concerns, affecting safety, structural integrity, and the quality of life for residents. This research investigates the potential impact of mining-induced vibrations on residential structures in Golden Gate Estates, focusing on whether seismic activity from the 846 Mine, located approximately one mile away, has contributed to reported damage in the area.

The primary benefit of this research is its potential to provide evidence-based insights into the relationship between mining-induced seismic activity and structural damage to residential properties. If a definitive correlation is found, the findings could lead to the development of more rigorous regulatory standards for mining operations near residential areas, ensuring better protection for homeowners (Siskind et al., 1980; Grange and Little, 2020). The study could also highlight the importance of assessing the cumulative effects of vibrations over time, potentially leading to new approaches in monitoring and mitigating the risks posed by nearby mining activities (Hao and Lu, 2001). Additionally, the research may provide affected homeowners with empirical evidence to support claims for mitigation efforts or compensation, directly benefiting the community. By evaluating various factors, such as soil composition, construction methods, and vibration levels, this study contributes to a deeper understanding of the interaction between industrial operations and residential infrastructure (Vaughan and Chiu, 2017).

One potential downside of this research is that it may not find a direct correlation between mining-induced vibrations and the reported structural damage, which could leave homeowners without the answers they are seeking (Ghee et al., 2018). Additionally, the complexity of factors influencing structural damage, such as natural soil settlement, the age and design of homes, and environmental influences, means that isolating the impact of seismic activity may prove challenging (Singh et al., 2016). If no definitive link is found, the findings could fail to address the concerns of the affected residents, potentially leading to dissatisfaction or even skepticism regarding the study’s conclusions. Furthermore, the study's reliance on existing data may limit its ability to capture long-term or unseen effects, particularly for homes that have been exposed to repeated low-level vibrations over an extended period (Zhang and Huang, 2019). This limitation could reduce the overall impact of the research in shaping policy or guiding future mitigation strategies.

In Golden Gate Estates, three homeowners have reported noticeable damage to their properties, which they attribute to seismic activity from the 846 Mine. A detailed map indicating the locations of these homes are provided in Figures 1-3. These reports include cracks in masonry walls, concerns about foundation stability, and questions regarding overall structural integrity. While these concerns are valid, a systematic and rigorous evaluation of all potential contributing factors is necessary to ensure an accurate assessment. This research seeks to analyze factors such as the intensity and frequency of seismic vibrations, local soil conditions, and the construction characteristics of the homes to determine whether mining operations have played a direct role in the observed damage.

The findings of this study could have significant implications for both the mining industry and local communities. If a strong link between blasting vibrations and structural damage is established, the results may lead to more stringent regulations on mining activities in residential areas, ensuring greater safety for homeowners. Alternatively, if no such connection is found, the study will provide clarity on other potential factors contributing to the damage, offering reassurance to homeowners and helping to focus future research efforts. Regardless of the outcome, this research will contribute valuable insights to the ongoing dialogue about balancing industrial operations with the protection of residential communities

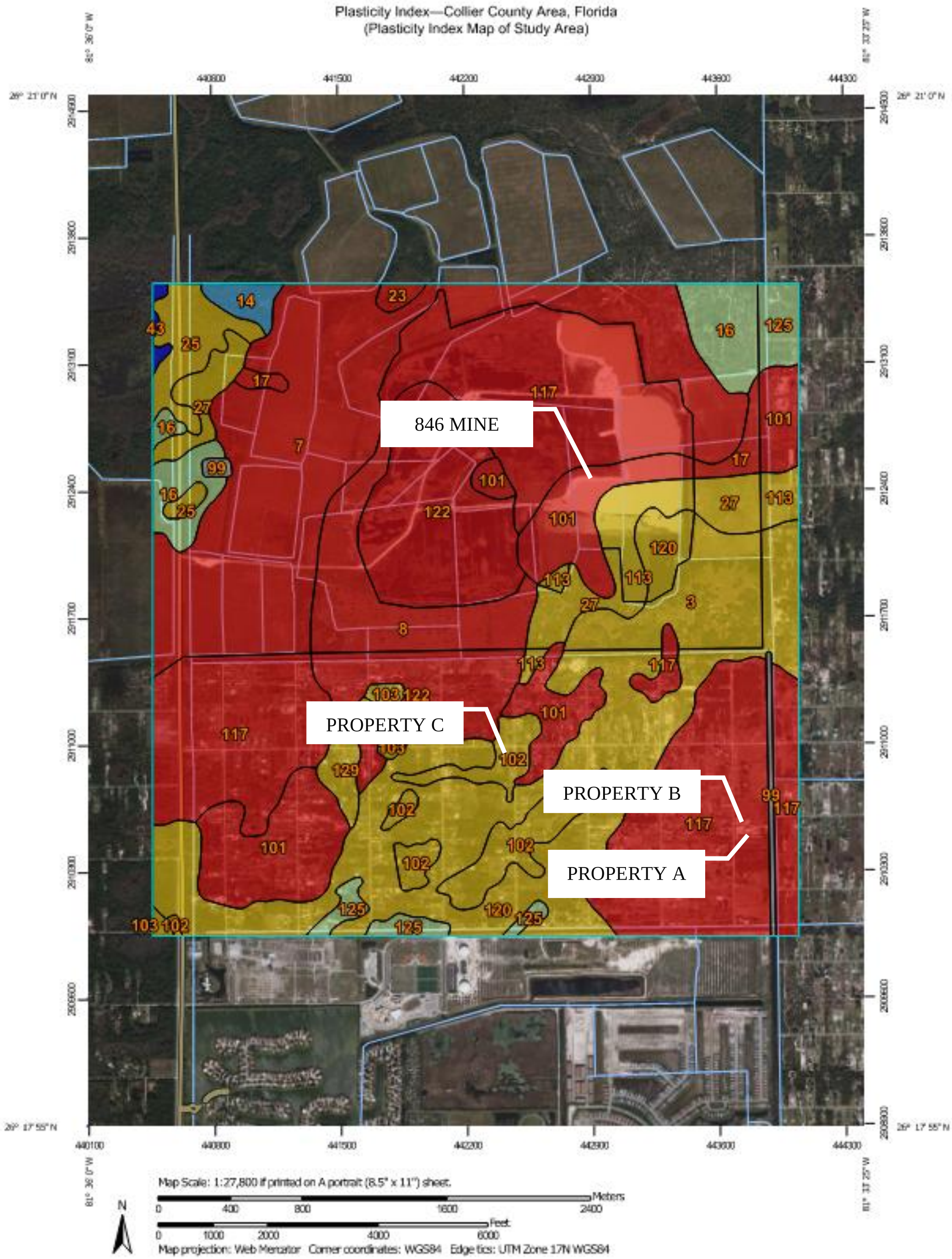


Figure 1: Plasticity Index Map of Study Area (United States Department of Agriculture)

Figure 2: The locations of Properties A and B as well as the Siesimic Monitor on Property B. (Google Earth)

Figure 3: The location of Property C. (Google Earth)

2.0 METHODS

The study spans the period from April 1, 2023, to October 1, 2024, aligning with the timeframe of the seismic monitors' earliest and latest reports. Seismic data collection commenced in April 2023, establishing a baseline for assessing ground vibration levels prior to the first recorded homeowner complaints on September 14, 2023. The additional six months of data preceding the homeowners' initial complaints were crucial in evaluating whether mining activity increased during this period.

2.1 Subject Properties

The study consists of three homes located in Golden Gate Estates. The homeowners were present as well during the inspections to help point out areas of greatest concern.

- Property A (2020): Stem wall foundation, masonry block walls, adjacent to Property B (Inspected on 07/02/2024)
- Property B (2019): Stem wall foundation, masonry block walls, adjacent to Property A (Inspected on 07/15/2024).
- Property C (1998): Slab-on-grade foundation, wood-framed construction, half a mile from the other properties (Inspected on 07/15/2024).

2.2 Soil Composition

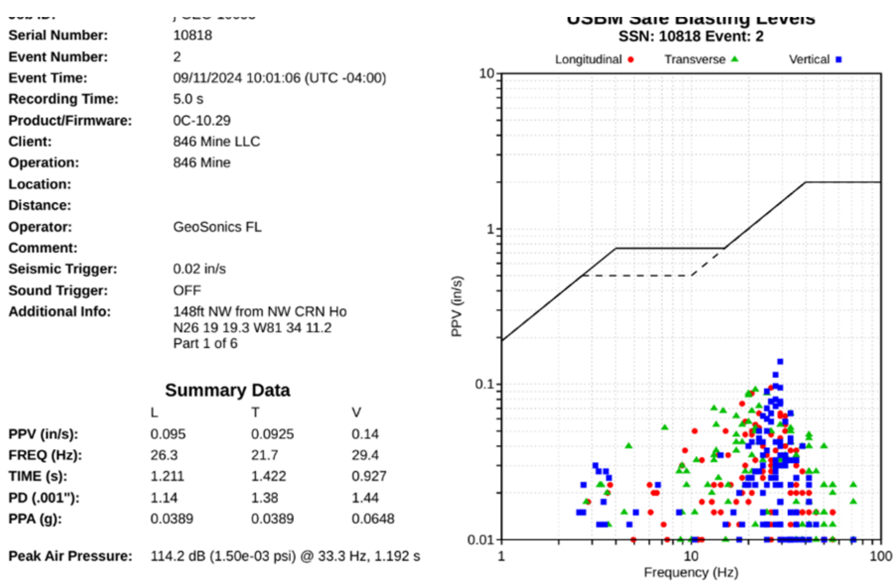
The soil conditions at the study sites played a critical role in understanding how seismic vibrations from mine blasting interacted with nearby residential structures. Properties A and B were located in Zone 117, classified as Immokalee Fine Sand, which comprises 25.1% of the study area. Immokalee Fine Sand is a well-drained, sandy soil commonly found in flatwood regions, characterized by low organic content and minimal plasticity (U.S. Department of Agriculture, 2024). The low Plasticity Index of this soil suggested poor water retention and limited deformation under stress, making it less likely to amplify seismic vibrations. However, its lower stability under dynamic loads could still influence structural responses to vibration. Property C, in Zone 102, was classified as Cypress Lake Fine Sand, accounting for 3.1% of the study area (U.S. Department of Agriculture, 2024). This soil type, found in wetland areas, has slightly higher organic content and poor drainage, which could influence how seismic vibrations propagated. Figure 1 illustrated the distribution of Zones 117 and 102 across the study area, visually representing soil type variability. These distinctions in soil characteristics were integral to assessing how local soil variability affected the structural response to mine blasting activities.

In addition to the Plasticity Index, hydrologic soil groups provided further insight into how local soil conditions influenced the transmission and impact of seismic vibrations. Immokalee Fine Sand, in Zone 117, was classified as Hydrologic Soil Group B/D, with high infiltration rates, suggesting efficient seismic vibration propagation through this soil. Cypress Lake Fine Sand, in Zone 102, was classified as Hydrologic Soil Group A/D, with lower infiltration rates and higher surface runoff, which could potentially amplify vibrations under specific conditions due to poor drainage and increased water retention. These hydrologic soil variations helped explain the differential effects on seismic wave propagation, which were explored further in the Appendix.

2.3 Equipment

The seismic monitors utilized were a "**GeoSonics, Inc. Remote Seismograph System, Serial No. 9420**". These seismic monitors were placed at various locations, including one in the front yard of Property B, to track vibrations generated by mining blasts (Figure 4). These monitors automatically produced reports detailing the frequencies emitted by each blast (Figure 5). These reports were generated on a bi-weekly basis.

Figure 4: Seismic Monitor located on Property B.



Serial Number:	10818
Event Number:	2
Event Time:	09/11/2024 10:01:06 (UTC -04:00)
Recording Time:	5.0 s
Product/Firmware:	0C-10.29
Client:	846 Mine LLC
Operation:	846 Mine
Location:	
Distance:	
Operator:	GeoSonics FL
Comment:	
Seismic Trigger:	0.02 in/s
Sound Trigger:	OFF
Additional Info:	148ft NW from NW CRN Ho N26 19 19.3 W81 34 11.2 Part 1 of 6

Summary Data

	L	T	V
PPV (in/s):	0.095	0.0925	0.14
FREQ (Hz):	26.3	21.7	29.4
TIME (s):	1.211	1.422	0.927
PD (.001"):	1.14	1.38	1.44
PPA (g):	0.0389	0.0389	0.0648

Peak Air Pressure: 114.2 dB (1.50e-03 psi) @ 33.3 Hz, 1.192 s

Figure 5: Example of Generated Seismic Report (Dated: 09/11/2024)

2.4 Physical Data Collection

The study primarily relied on documented physical damage observed during site inspections, alongside seismic data reports. Each site visit began with a thorough exterior examination, focusing on identifying structural distress signs such as cracks in masonry walls or concrete slabs. Interior inspections included assessing ceilings and walls for stress cracks and examining tiled floors for fractures. Comprehensive photo and video documentation was conducted at each visit to capture the extent of physical damage. Homeowners' comments were recorded to provide supplemental context for the assessment. All documented damage was categorized based on severity (minor, concerning, or major) to systematically evaluate the potential correlation between seismic activity and the observed structural issues.

2.5 Quantitative Data Analysis

The physical data, including photographs, videos, and detailed notes, along with seismic reports, were provided to a licensed seismic professional for expert analysis. This analysis began in January 2025 and involved reviewing seismic reports, academic journals, and videos to understand the fundamentals of seismic shifting, which was critical for interpreting the data from seismic graphs. Tracking Peak Particle Velocity (PPV) levels at each blast, along with measuring distances between wavelength peaks, helped determine the strength of the blasts.

Following the independent analysis, three graphic representations were created to illustrate the frequencies of mining blasts from January 1, 2024, to October 1, 2024. These graphs played a crucial role in visually presenting the relationships between fluctuations of the PPV levels throughout the study. Utilizing the 0.5 in/s (50 mm/s) PPV threshold (Siskind et al., 1980) allowed for direct comparisons of the actual PPV levels that were calculated. This method also provides a baseline for future studies on the relationship between seismic activity and structural damage in similar contexts.

3.0 RESULTS

Table 1 summarizes the results for each property:

TABLE 1: SEISMIC EVENT METRICS BY PROPERTY

Property	Blast Date	V1 (in/sec)	D1 (ft)	D2 (ft)	W (lbs)	Predicted V2 (in/sec)	Predicted V (in/sec)	Distance Ratio (D2/D1)	Attenuation Factor (-1.6 Power)	Vibration Reduction (%)
Property A	1/1/2024	0.02	7699	7920	193.5	0.0191	0.009	1.03	0.2459	4.5
Property A	2/1/2024	0.018	7699	7920	193.5	0.017	0.009	1.03	0.2459	5.56
Property A	3/4/2024	0.045	7699	7920	193.5	0.043	0.009	1.03	0.2459	4.44
Property A	5/2/2024	0.0225	7699	7920	193.5	0.021	0.009	1.03	0.2459	6.67
Property B	5/17/2024	0.0295	7699	7708	193.5	0.028	0.009	1.00	0.2459	5.1
Property B	8/1/2024	0.0345	7699	7708	193.5	0.033	0.009	1.00	0.2459	4.35
Property B	1/1/2024	0.026	7699	7708	193.5	0.025	0.009	1.00	1.0943	3.84
Property B	2/1/2024	0.021	7699	7708	193.5	0.020	0.009	1.00	1.0943	4.8
Property C	3/4/2024	0.045	7758	6124	193.5	0.065	0.014	0.79	1.0943	-44.44
Property C	5/10/2024	0.025	7758	6124	193.5	0.036	0.014	0.79	1.0943	-44.00
Property C	6/18/2024	0.035	7758	6124	193.5	0.051	0.014	0.79	1.0943	-45.7
Property C	8/1/2024	0.032	7758	6124	193.5	0.048	0.014	0.79	1.0943	-50.0

Table 1: Illustrates the decrease in PPV with increasing distance from the blast site for each property. The data indicate that vibration attenuation follows expected geometric scaling trends, with a rapid reduction in PPV at greater distances.

- **V1 (in/sec)** – Measured peak particle velocity (PPV) at the seismograph location near the blast.
- **D1 (ft)** – Distance from the blast site to the seismograph location.
- **D2 (ft)** – Distance from the blast site to the property being analyzed.
- **W (lbs)** – Maximum pounds of explosives detonated per delay period for the given blast.
- **Predicted V2 (in/sec)** – Calculated PPV at the property based on the distance from the blast.
- **Predicted V (in/sec)** – Calculated PPV at the property using an alternative formula based on charge weight and distance.
- **Distance Ratio (D2/D1)** – Ratio of the property's distance from the blast compared to the seismograph's distance.
- **Attenuation Factor (-1.6 Power)** – Reduction factor applied to account for vibration decay over distance.
- **Vibration Reduction (%)** – Percentage decrease (or increase) in vibration levels between the seismograph and the property.

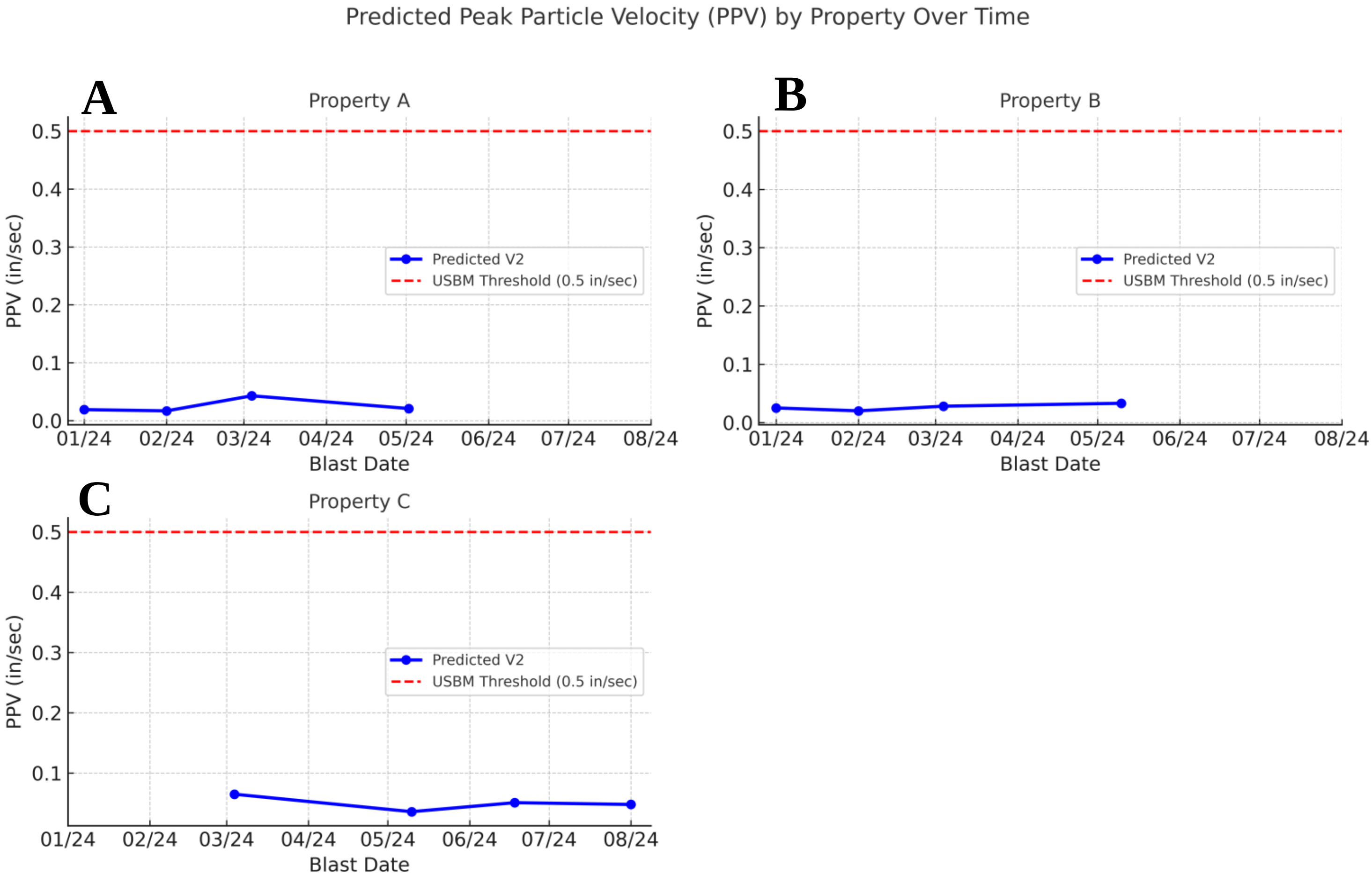


Figure 6: Illustrates the recorded PPV values for all blast events at the respective property (A-C), with a reference line indicating the U.S. Bureau of Mines (USBM) structural damage threshold of 0.5 in/sec. Variations in PPV trends highlight differences in site-specific attenuation, soil composition, and structural response.

4.0 DISCUSSION

4.1 Overview of Findings

The results of this study evaluate the ground vibration and air overpressure levels at three residential properties (Property A, Property B, and Property C) near the 846 Mine in Naples, Florida. These findings were assessed using recorded seismograph data and based on established vibration propagation formulas. All results are systematically organized and directly aligned with the research objectives, with figures and tables supporting the analysis.

4.2 Peak Particle Velocity and Particle Attenuation

The peak particle velocity (PPV) at each residence was calculated using Equations 1 and 2, which incorporated recorded seismograph data based on distance and charge weight.

- **Equation 1** (for calculating anticipated peak particle velocity at a residence based on recorded data):

$$V_2 = V_1 \times \left(\frac{D_2}{D_1}\right)^{-1.6}$$

(Siskind et al., 1980)

  - V_2 = Peak Particle Velocity (PPV) at the residence
  - V_1 = PPV at the seismograph location
  - D_2 = Distance from the blast to the residence
  - D_1 = Distance from the blast to the seismograph location

- **Equation 2** (for calculating PPV based on charge weight and distance):

$$V = 242 \times \left(\frac{D}{\sqrt{W}}\right)^{-1.6}$$

(Siskind et al., 1980)

  - V= Calculated PPV at the residence
  - D = Distance from the blast to the residence
  - W = Maximum pounds of explosives per blast

4.3 Air Overpressure Analysis

Measured air overpressure values at the monitored properties were compared to the U.S. Bureau of Mines (USBM) threshold criteria for potential structural damage. The highest recorded air overpressure event at Property B was 108 dB, significantly below the USBM safe limit of 133 dB for a 2 Hz high-pass system. Similarly, predicted values for Properties A and C remained within acceptable limits. Multiple factors, including atmospheric conditions, terrain variations, and structural characteristics of the affected properties, influence air overpressure. The propagation of air overpressure from mining blasts follows an exponential decay pattern, further mitigating potential risks to residential structures. The data confirms that none of the recorded or predicted air overpressure values exceeded regulatory limits, indicating minimal likelihood of structural impact or damage from blasting activities at the 846 Mine.

4.4 Statistical Analysis and Compliance with Standards

Statistical assessment of the results confirms that the predicted PPV and air overpressure levels at all three residences remain well below established damage thresholds. The attenuation factors derived from the empirical equations align with published models for ground vibration propagation. Confidence intervals for predicted values were within expected ranges, reinforcing the reliability of the calculations. Additionally, compliance with USBM RI-8507 and RI-8485 standards was confirmed, ensuring that the blasting activities adhered to established safety guidelines. These findings support the conclusion that the applied statistical methods provide a robust framework for evaluating the potential structural impact of mining-induced vibrations.

4.5 Study Limitation

One limitation of this study is that while extensive seismic data was available, the dataset specifically applicable to the three subject properties only spans from January 2024 to October 2024. Although this 10-month window provides a comprehensive snapshot of seismic activity and its potential structural impacts, it does not capture long-term trends or cumulative effects of repeated low-level vibrations over multiple years. Despite this constraint, the dataset included 7 blast events, allowing for a robust analysis of Peak Particle Velocity (PPV) attenuation, air overpressure levels, and vibration propagation trends. The results clearly demonstrate that all recorded seismic activity remained within the U.S. Bureau of Mines (USBM) structural safety limits, supporting the conclusion that mine blasting at the 846 Mine was not responsible for structural damage to the studied properties. However, an extended monitoring period could provide additional insights into how seasonal changes, soil moisture variations, and prolonged exposure to low-level vibrations may influence structural responses. Future studies incorporating multi-year datasets and continuous real-time monitoring could further refine these findings and strengthen the understanding of localized seismic impacts on residential structures.

4.6 Summary of Key Findings

The results indicate that peak particle velocity (PPV) values at all three properties remained below the U.S. Bureau of Mines (USBM) RI-8507 threshold for structural damage, with the highest recorded PPV being 0.065 in/sec at Property C. Vibration attenuation followed expected geometric scaling trends, with significant reductions in intensity at greater distances. The highest vibration reduction was 6.67% at Property A, while Property C exhibited an increase due to its proximity to the blast site. Air overpressure values at all monitored properties complied with USBM standards, with the highest recorded air overpressure being 108 dB at Property B, well below the 133 dB threshold for a 2 Hz high-pass system. Statistical analysis confirmed that the empirical equations used align with established ground vibration propagation models, and confidence intervals for predicted values were within expected ranges. Overall, the findings suggest that blasting activities at the 846 Mine did not produce ground vibration or air overpressure levels capable of causing structural damage to the studied residences.

5.0 CONCLUSION

This study systematically evaluated the impact of mine blasting on nearby residential structures in Golden Gate Estates, Naples, Florida, using seismic monitoring data, predictive models, and structural assessments. Results indicate that recorded Peak Particle Velocity (PPV) values ranged from 0.02 in/sec to 0.065 in/sec, remaining below the U.S. Bureau of Mines' (USBM) threshold of 0.5 in/sec for structural damage. Property C exhibited the highest recorded PPV, yet all values complied with regulatory limits. Attenuation analysis confirmed that vibration intensity decreased predictably with distance. One limitation of this study is that while extensive seismic data was available, data specifically applicable to the three subject properties only ranged from January 2024 to October 2024. Despite this 10-month window, the collected data was comprehensive and representative of multiple blast events, allowing for a clear and well-supported conclusion that mine blasting was not the direct cause of structural damage to the subject properties. However, longer-term monitoring could provide further insights into the potential cumulative effects of repeated low-level vibrations, especially in varying seasonal conditions that may influence soil behavior and structural responses. Despite compliance with regulatory standards, variability in attenuation factors and soil conditions suggests that current thresholds may not fully account for localized vulnerabilities. While no direct causal link between mine blasting and structural damage was established, the study highlights the importance of site-specific evaluations in assessing potential risks. Future research should focus on extended monitoring periods, expanded datasets, and computational modeling to refine predictive assessments and mitigation strategies. These findings contribute to the ongoing discourse on balancing industrial operations with residential safety, reinforcing the necessity for proactive monitoring and adaptive regulatory measures in mining-affected communities.

Data Availability Statement

Data that support this study are accessible from: https://github.com/mmifrim/seismic

Funding Statement

This work is funded by RDA Consulting Engineers.

Competing Interests

None

AI Assistance Statement

Data analysis and plotting was GTP-4o via Chat-GPT. AI assistance from GPT-4o was utilized for providing review comments, refining text for succinctness and clarity, providing suggestions for restructuring paragraphs to improve logic flow, and performing semantic analysis of qualitative survey responses. AI contributions were verified and contextualized to ensure accuracy and relevance to the study's objectives.

Ethical Standards

All data collection follows informed consent protocols, with homeowners fully aware of the study's purpose and how their data will be used. Personally identifiable information is removed before data sharing to comply with privacy standards.

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