Flood Risk and Property Value:

A Case Study Analysing the Effect of Disclosed Flood Risk Maps on the Housing Market in Hamilton, New Zealand

A thesis

submitted in partial fulfilment

of the requirements of the degree of

Master of Environmental Planning in the Faculty of Arts and Social Sciences

at

the University of Waikato

by

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2025

Abstract

Flooding is among the most financially devastating natural disasters globally and in New Zealand. To manage flood risk, educating the public about its potential dangers is widely recognised as a necessity worldwide. However, in New Zealand, building development and property sales continue to thrive in officially designated flood risk areas, suggesting that published flood risk information may not be achieving its intended impact. This raises alarming concerns about whether the public effectively receives published flood risk information and to what extent it influences their decision making. However, empirical research on this topic is scarce in New Zealand, and the few existing studies only cover small portions of a case study area, lacking broader geographical representation and transferrable insights into long-term behavioural responses to flood risk information. This leaves local governments without reliable evidence to assess the effectiveness of flood risk disclosures and informed land-use decisions. One of the key reasons is the lack of nationally consistent flood risk mapping and the fragmented flood risk management approach across localities and regions, making flood risk information scattered, inconsistent, and difficult to access.

This research aims to address this gap by conducting a comprehensive empirical analysis in Hamilton City, New Zealand. Specifically, I focus on the holistic timeline of flood risk information released within the city since the first flood map was officially adopted in 2012. Specifically, Hamilton City Council (HCC) released flood risk maps and adopted them in the 2012 District Plan, followed by the introduction of online Floodviewer maps in 2020. Publishing flood risk information through two different platforms covering various urban spaces makes this a unique case study for examining the effects of flood risk on property prices. This research combines rigorous causal inference methods, including Difference-in-Differences (DID), Repeat-Sales models, and Hedonic modelling, to examine whether the release of flood risk information influences property sales in officially designated flood zones. The Results show that flood risk information has a limited impact on property prices in Hamilton City's flood risk areas. However, in repeat sales analysis, disclosing flood risk information positively impacts housing value in these areas. These findings align with most historical research in New Zealand, indicating that it is not rare for people to disregard flood risk information in this country. This may be attributed to the absence of a unified national standard for published flood risk information and the lack of effective communication mechanisms.

Acknowledgments

After one year of training and practice, I deeply appreciate the invaluable experience of completing this master’s project. This journey has provided me with numerous opportunities to develop research, project management, data analysis, communication and academic writing skills. With these skills, I believe I am equipped to tackle complex challenges in my future career and research endeavours. I would first like to express my sincere gratitude to my project supervisor, Dr. Xinyu Fu. Thank you for inviting and encouraging me to apply for this unique opportunity to study at the University of Waikato Te Whare Wānanga o Waikato. Your support, guidance, and constructive feedback have been invaluable in supporting me throughout my master's project. I would also like to thank my family for encouraging me to continue my studies at this stage of my life. Compared to most of my peers in my hometown, choosing to continue my studies while being 30 years old often has required great courage. Thank you for supporting my decisions. Finally, I would like to express my sincere appreciation to the staff of all local governments who responded to my inquiries and emails. Thank you for clarifying for me and providing important data for this research. Without your support, this research would not have been possible.

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1 Introduction

Floods are among the most financially devastating natural disasters both globally and in New Zealand (Roy and Noy 2023; Pastor-Paz et al. 2020; Mason et al. 2021). Since 2000, they have cost the Earthquake Commission,[1] the national public insurer of New Zealand, a staggering 450 million NZD (Pastor-Paz et al. 2020). Such a significant expense is mainly because of the fact that more than half of New Zealand's population lives in flood-prone areas, with many urban areas built on floodplains (Mason et al. 2021). To manage flood risk, the New Zealand Government has implemented significant measures. One common approach is building government-funded protective structures (stopbanks, reservoirs, and levees) to mitigate flood risk (Fu et al. 2023). Another strategy involves regulating land use in high-risk areas (Nguyen et al. 2021; Glavovic, Saunders and Becker, 2010). Meanwhile, the legal system has sought to shift the primary responsibility of flood risk management from central government to local councils (Walsh, Paulik and Robertson 2019). Policies such as the Land Information Memorandum (LIM) report [2] and the Local Government Act 2002 have facilitated this transition. This approach enables local governments to provide more tailored flood risk information based on specific local circumstances.

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[1] From 1 July 2024, the Earthquake Commission has been replaced by the Natural Hazards Commission Toka Tkū Ake. For more details, see the Natural Hazards Commission website: https://www.naturalhazards.govt.nz/about-nhc/how-we-work/natural-hazards-insurance-act-2023.

[2] Local governments prepare a LIM report upon request to provide a summary of the current information on a property. Typically, it will take 10 days to prepare and needs a fee. An additional fee may be required for a fast-tracking. For more information on what a LIM report is, see Settled.govt.nz, "What Is a LIM Report?" accessed October 20, 2024, https://www.settled.govt.nz/blog/what-is-a-lim-report/.

In addition to these methods, disclosing flood risk information to the public plays a vital role in flood risk management. According to the Greater Wellington Regional Council (2022), published flood risk information can raise public awareness, support decision-making processes, and optimise future land use. As a result, this approach has been widely adopted by many local authorities in New Zealand (Walsh, Paulik and Robertson 2019). In addition to supporting the aforementioned management measures, it may influence stakeholders' behaviour in the housing market, especially those who own properties in flood risk areas (Beltrán, Maddison and Elliott 2018; Seebauer and Winkler 2020). Unfortunately, despite the increased accessibility and accuracy of the risk information, construction activities continue to thrive in flood risk areas in New Zealand. Newton (2024) reported that 1,415 new home consents were granted in floodplains in Auckland within one year after the 2023 flooding disaster. While this trend reflects a thriving construction industry and a booming housing market, it also raises a concern about whether the flood risk information has been effectively communicated, understood and incorporated into the housing market.

This issue has been widely examined on a global scale. Within these studies, numerous have found a negative relationship between flood risk information and property prices (Van Assen 2024; Békés, Áron and Zoltán 2016; Hsieh 2021; Miller and Pinter 2022). This relationship can serve as evidence of whether risk information is effectively communicated to the public. However, in New Zealand, findings from researchers fail to establish a consistent consensus about the effect of disclosed flood risk information on housing prices. The reasons for this situation are multiple. First, nationwide studies on this topic are absent in this country. In countries such as England (Belanger and Bourdeau-Brien 2017), the United States (Hino and Burke 2021), Hungary (Békés, Áron and Zoltán 2016), nationwide studies can help to summarise a broad overview and serve as a foundation for large-scale land-use regulation (Lo, Noble and Freemark 2023). In contrast, in New Zealand, studies examining the relationship between flood risk information and housing prices are primarily case studies, each focusing on a small area within a specific city (Nguyen et al. 2019; Nguyen et al. 2022; Cheung and Yiu 2022; Filippova et al. 2020). This may be due to the absence of a nationally unified standard for flood risk information (Walsh, Paulik and Robertson, 2019). Meanwhile, because of the diverse geographical environments and socioeconomic conditions across various urban areas in this island country, it is difficult to extrapolate the reflection of housing markets in other cities based on existing results.

Second, in recent decades, all existing research in New Zealand on similar topics has focused exclusively on coastal urban areas and has yielded conflicting conclusions. In the limited number of studies on this topic, only those studies in Dunedin align with global mainstream studies (Nguyen et al. 2019; Nguyen et al. 2022), which suggest that flood risk information can decrease housing prices in Dunedin. In contrast, other case studies have found no significant influence (Cheung and Yiu 2022; Filippova et al. 2020). This suggests that even if an attempt were made to conclude an overall trend based on these studies, the lack of research on inland urban areas and the inconsistency of findings would make this attempt unlikely to succeed.

Therefore, this study will focus on Hamilton City and conduct a regression analysis using a framework that combines the Difference-in-Differences (DID) approach with the Repeat-Sale model to analyse the effects of flood risk disclosure on the housing market. This provides more reliable evidence for future urban planning in this city and also offers insights into the local housing market in inland urban areas that have been largely overlooked. Meanwhile, it will validate a reliable research method for future studies in New Zealand. First, Hamilton is the largest inland city in New Zealand. As mentioned, the lack of studies focused on inland urban areas and the diverse urban contexts across different cities has left local councils without sufficient criteria to assess whether their information disclosure efforts are practical. This research fills this gap and provides more reliable evidence to support the city council's future land-use and planning decisions.

Secondly, this research confirms that combining the DID approach and the Repeat-Sale model provides a more reliable method for assessing the effects of flood risk information on the housing market. Compared to the traditional Hedonic model based on cross-sectional data, the DID framework introduces three key variables: a treatment group dummy, a time period dummy, and their interaction term. This effort classifies transactions into treatment and control groups and compares price changes before and after the treatment (implementing policies or disclosing flood risk information). This isolates the causal effects of the treatment, specifically the disclosure of flood risk information, and therefore addresses the endogeneity problem in traditional Hedonic models (Banzhaf 2021). While the DID model effectively assesses the differences between the treatment and control groups, it still has limitations in controlling for unobserved heterogeneity and spatial spillover effects of policies (Benzhaf 2021). Therefore, the Repeat-Sale model is introduced alongside the DID approach to form an integrated framework in this study. By utilising the panel dataset for matched transactions, it tracks the same properties over time. This effectively eliminates the impact of varying housing characteristics, allowing the analysis to focus more on the effect of the policy or event itself (Case and Shiller 1989). The limitation of relying on a panel dataset with a restricted sample size (Belanger and Bourdeau-Brien 2017) is mitigated through its integration with the DID model. Both models consistently indicate that in Hamilton, the disclosure of flood risk information has not attracted buyers' attention. This aligns with the results of several other studies in New Zealand, except the research conducted by Nguyen et al. (2019, 2020). Such consistency also suggests that buyers in multiple urban areas may share similar considerations and tend to overlook flood risk information when purchasing a property in New Zealand. Therefore, this research successfully validates the reliability and robustness of the combination of DID and the Repeat-Sale model, demonstrating that this approach can effectively detect potential price alterations caused by disclosure events, which cannot be captured by the traditional Hedonic model (Hino and Burke 2021).

Finally, the results further confirm that, based on the transaction dataset with a sufficient sample size, the methodology employed in this research remains reliable in capturing the impact of complex disclosure events. This is particularly relevant because most urban areas in New Zealand are undergoing a series of flood risk information disclosures (Auliagisni, Wilkinson and Elkharboutly 2022; Walsh, Paulik and Robertson 2019), and in Hamilton, these disclosures include the publication of a floodplain map in the 2012 district plan, which was communicated through paper-based documents (Hamilton City Council 2012) and the launch and subsequent updates of the online Floodviewer, beginning in 2020 (Email communication with author, October 11, 2024). The primary distinction between these two disclosure events involves the transition from paper-based reports to online updates and the expansion of flood risk areas.

By assessing and comparing these disclosures' regression results, this study further validates the robustness of its approach in examining various disclosure events. This provides a solid foundation for future studies on similar topics in New Zealand, whether focusing on another urban area or conducting a nationwide analysis.

Building on these objectives, this research is structured as follows, to examine the effects of disclosing flood risk information on the local housing market in Hamilton. It begins with a literature review, providing the background of this study and highlighting the importance of investigating the effect of disclosing flood risk information on housing prices. Next, relevant background information about Hamilton City will be presented. This study then details the transaction data cleaning process and the models employed in this research. This is followed by a presentation of empirical results. Based on these results, this research will discuss the consequences and potential reasons why flood risk information is presently neglected. Finally, recommendations for future development and further studies will also be made.

2 Literature Review

2.1 Importance of Flood Risk

Throughout human history, flooding has been one of the most devastating natural disasters, drawing significant attention from urban planners and policymakers. On a global scale, flooding events have caused countless losses to the local economy and infrastructure. Numerous studies report that flood events destroy properties and facilities, lead to homelessness, and place substantial pressure on financial systems (Contact, Hopkins and Mejia 2024; Bin and Kruse 2006; Hallstrom and Smith 2005). For example, Hurricane Sandy was the second-largest Atlantic hurricane in US history, and the following flooding caused approximately $50 billion in losses across the Eastern Seaboard (Blake et al. 2013). In the UK, with more frequent flood events, an increasing number of residents have witnessed the damage flooding inflicts on properties (Lamond, Proverbs and Hammond 2010). Additionally, assets worth over £200 billion are estimated to be at risk from flooding (Foresight Programme 2004). Similar extensive damage has also been reported in Australia (Rajapaksa et al. 2016), Hungary (Békés, Áron and Zoltán 2016), Argentina (Rabassa and Zoloa 2016), and other countries. In New Zealand, flooding is also a frequent and highly destructive natural disaster. Between 2007 and 2017, the 12 biggest flooding events resulted in approximately 140.48 million New Zealand dollars (NZD) in economic losses (Frame et al. 2020). The extreme flood in Dunedin caused by heavy rainfall on June 3, 2015, led to about 28 million NZD in cost of insurance payouts. About 1200 homes and businesses were damaged during the event (Stuff 2019).

Unfortunately, due to climate change and its impact on sea-level rise, flooding events are becoming increasingly frequent and intense, as highlighted in the IPCC’s Climate Change 2023: Synthesis Report (IPCC 2023). According to research conducted by Nguyen et al. (2019, 2022), by 2050, at least 570 cities and around 800 million people will be exposed to flood risks due to rising sea levels and storm surges. Smart and McKerchar (2010) highlight that with population growth leading to increased housing development in flood-prone areas and heavy rainfalls in more populated regions, New Zealanders face an unavoidable increase in flood-related damage from flood events.

To manage increasing flood risk, local authorities typically tailor their strategies to align with specific risk profiles, available technical expertise, and financial resources (Greater Wellington Regional Council 2022; Penning-Rowsell et al. 2013; Yiannakoulias et al. 2018). Fortunately, various research studies and government reports have helped summarise some widely-accepted strategies. One of the primary approaches involves structural measures, which include infrastructure such as stopbanks, drainage systems, and other protective installations to prevent potential flooding damage (Fu et al. 2023). Ramasamy et al. (2023, 7) stated that this method effectively protects “communities, agricultural land, and critical facilities from floodwaters.” New Zealand has also heavily relied on such protections as part of the traditional flood risk management system (Fu et al. 2023). However, Smart and Mckerchar (2010) warned that these protections may lead people to forget the risk of potential intense flooding events. Once the protection level is exceeded, the resulting damage can be even more severe. In addition, Fu et al. (2023) found that in New Zealand, local governments are facing more pressure to maintain and upgrade flood protective infrastructure because of climate change and the increasing population numbers in flood-prone areas, but financial resources are lacking.

Besides structural protection, governments have also adopted non-structural measures such as regulations and incentives to encourage (or even force) owners to purchase necessary insurance for their properties (Dei-Tutu 2002; Lamond, Proverbs and Antwi 2007; Yi and Choi 2019; McCoy and Zhao 2018). This approach requires the property owner and insurer to identify whether a property is located in a floodplain but also estimates the extent of potential damage, as reflected in the varying insurance premiums for different properties (Dei-Tutu 2002; McCoy and Zhao 2018). In New Zealand, a dual insurance system is in place. While the government-operated Earthquake Commission (EQC) provides basic coverage with a fixed rate of 15 cents per 100 NZD of insured value, property owners can also purchase additional insurance through private providers (Pastor, Noy and Sin 2018). However, several issues continue to limit the effectiveness of flood insurance (Lamond, Proverbs and Antwi 2007). The primary concern is the low purchase rate (Graham, Hall and Schuhmann 2007; Dei-Tutu 2002). A notable example is that even after regulation was introduced requiring owners whose property is in the Special Flood Hazard Area (SFHA) to purchase flood insurance, the uptake rate remained low (Graham, Hall and Schuhmann 2007; McCoy and Zhao 2018). In New Zealand, insurance uptake is also generally low (Araullo 2024), especially in low-income households and for individuals in rural areas (Aon 2021). Moreover, even when owners purchase necessary flood insurance, losses in flooding events may not be fully covered (Dei-Tutu 2002; Gourevitch et al. 2023; Hino and Burke 2021). As a result, due to the limited coverage provided by EQC (Insurance Business, 2024), owners may face significant costs, which can exceed EQC's standard (Pastor, Noy and Sin, 2018).

Designating special land-use zones is another widely accepted non-structural flood management strategy accepted by many countries (Contat et al. 2024; Bin and Kruse 2006; Hallstrom and Smith 2005; Lamond, Proverbs and Hammond 2010). The Special Flood Hazard Area (SFHA) in the United States is considered one of the most well-known designated flood risk areas. It plays a crucial role in refining regulatory policies (Dei-Tutu 2002). In New Zealand, the regulations did not include a clear standard for the level of risk that should be controlled until the introduction of the 1992 Building Regulation (New Zealand Government 1992, Schedule 1, Clause E1.3.1). It states, "Surface water, resulting from an event having a 2% probability of occurring annually, shall not enter buildings" (1992, 47). To meet this requirement, flood protection zones in Palmerston North and Minimum Floor Level (MFL) in Dunedin were established after severe flood events.

Community-based approaches are also widely implemented at the local level. Integrating government-provided scientific methods with community knowledge offers highly effective solutions tailored to local conditions (Auliagisni et al. 2022; Greater Wellington Regional Council 2022). A key advantage of this approach is that active involvement fosters a deeper comprehension of flood risk at the local level, ultimately improving preparedness and resilience (Kreibich and Sairam 2022; Auliagisni et al. 2022). However, the public is not always willing to be part of such decision-making processes. Some individuals may be unaware of flood risk programs, while others may choose not to participate, believing they are not at significant risk of flooding (Auliagisni et al. 2022).

2.2 Flood Risk Information in Flood Risk Management

The effectiveness of the aforementioned flood risk management measures requires a critical prerequisite: a proper understanding of the flood risk, underscoring the growing importance of accurate flood risk information. (Abdrabo et al. 2020; Aterya and Czajkowski 2014; Hino and Burke 2021). Accurate flood risk information serves several essential functions to address the limitations of physical defences (Posey and Rogers 2010) and insurance systems (Yi and Choi 2019). Meanwhile, it is also a foundation for planning decision making (Nguyen et al. 2019) and influencing public behaviour.

First, published flood risk information can help raise awareness of potential hazards, especially when people become less vigilant about the possibility of severe floods that exceed the capacity of the flood protection infrastructure (Rajapaksa et al. 2016; Yi and Choi 2019). Additionally, it supports the insurance frameworks (Pastor, Noy and Sin 2018; Lamond, Proverbs and Antwi 2007). For example, based on the Special Flood Hazard Area (SHFA), America's National Flood Insurance Program (NFIP) clearly defines which property owners are required to purchase insurance.

Additionally, flood risk information has become a crucial foundation for governments to formulate relevant development policies (Walsh, Paulik and Robertson 2019). Nguyen et al. (2019, 2022) found that the Dunedin City Council designed a MFL area based on the announced 1-in-100-year flood risk zones. This policy requires all newly built properties in MFL areas to meet a minimum floor level standard. The Greater Wellington Regional Council's Guidelines for Floodplain Management Planning (2022) have similar requirements to govern future construction in flood risk areas.

Meanwhile, for the public, flood risk information can influence how people respond to flood events and risks (Beltrán, Maddison and Elliott 2018). For example, in America, there is a significant disparity in insurance uptake between property owners in the published flood risk areas and those outside such areas (Graham, Hall and Schuhmann 2007). Some studies also suggest that weighing the benefits of moving out against the cost of staying in flood risk areas is common (Seebauer and Winkler 2020; Tubridy and Lennon 2021). While some may choose to relocate due to emotional or financial concerns and uncertainty about the future (Seebauer and Winkler 2020), others may choose to purchase properties in the floodplain even though they have noted the flood risk (McCoy and Zhao 2018). Such effects highlight the critical role of flood risk information in shaping local housing markets.

2.3 Flood Risk Information and the Housing Market

Besides supporting flood risk management, flood risk information also plays a role in influencing housing prices. Numerous studies worldwide have confirmed this effect over the past few decades (Bélanger, Bourdeau-Brien and Dumestre 2018, 150; Gibson and Mullins 2020; Lamond, Proverbs and Hammond 2010; Posey and Rogers 2010). However, in some areas with sufficient public awareness, researchers suggest that updated flood risk information may not significantly influence housing prices (Votsis and Perrels 2015; Hsieh 2020). This may be because the local housing market has already developed stable expectations regarding flood risk, and as a result, newly released information may not significantly alter public perception, and thus re-evaluating housing prices may not be necessary (Hsieh 2020; Votsis and Perrels 2015).

Another notable phenomenon is the substantial disparity in property price discount rates across countries. This is because researchers have found that flood risk communicated through pre- and post-event methods affects the extent of price reductions (Hino and Burke 2021; Lamond, Proverbs and Hammond 2010). Post-event communication refers to the disclosure of existing flood risks following actual flooding events (Nguyen et al. 2022; Hino and Burke 2021; Lamon, Proverbs and Hammond 2010). This direct method is generally associated with identifying severe physical damage to properties, infrastructure, and communities (McCoy and Zhao 2018; Van den Honert and McAneney 2011; Arrighi, Pregnolato, and Castelli 2020). In addition to the direct physical damage expected to properties and infrastructures, this method can immediately inform the public which areas are at flood risk. Consequently, it can trigger a rapid and dramatic response in local housing markets. However, this method has a notable drawback. Without frequent reminders, local buyers may quickly forget the existing flood risk. Initially, while this can effect a decrease in property values by more than 20%, within a few years, this effect will gradually fade over time. In some cases, it may even disappear (Contat et al. 2024; Lamond, Proverbs and Hammond 2010; Ortega and Taşpınar 2018; Fisher and Rutledge 2021).

Pre-event communication usually involves announcing relative risk through flood risk maps or other similar methods (Hino and Burke 2021; NIWA 2019). This approach allows flood risk information to be conveyed to the public before actual flood events. Historical international research confirms that this method can exert a relatively moderate impact on housing markets (Hirsch and Hahn 2018; Zhang and Leonard 2018; Békés, Horváth and Sápi 2016), with price reductions generally not exceeding 10% following newly released flood risk information (Zhang and Leonard 2018; Beltrán, Maddison and Elliott 2018; Yeo 2003). However, this discount rate is not always similar or stable from one place to another. Hino and Burke (2021) argue that higher risk awareness can lead to a more significant discount rate in housing prices. The price effect can be both positive (Hino and Burke 2021) and negative (Zhang and Leonard 2018). Overall, such variations reflect to what extent a local market and buyers perceive and value flood risk information.

To quantify the impact of flood risk information on the housing market, the Hedonic model has been widely used by research worldwide (Beck and Lin 2020; Bin and Kruse 2006; Bin and Polasky 2004; Harrison, Smersh and Schwartz 2001; Hirsch and Hahn 2018; MacDonald et al. 1990). This approach helps identify the fundamental effect of a property's location within a floodplain. Additionally, by introducing the Difference-in-Difference method, many studies examine the impact of one-time flood risk disclosures within a specific area to reveal how the disclosure event influences property price reductions (Filippova et al. 2020; Zhang 2016). Meanwhile, some researchers have examined this effect on a larger scale (Békés et al. 2016; Belanger and Bourdeau-Brien 2017; Hino and Burke 2021). As a result, global historical studies have provided insights into why the impact of risk information varies across different locations. Additionally, such results revealed that researching the relationship between flood risk information and housing prices is essential to planners. Such research helps planners understand the local market in depth and assess the effectiveness of their policies.

2.4 Flood Risk and Relevant Research in New Zealand

As mentioned, New Zealand's unique location, topographical features, and climatic conditions contribute to a high flood risk nationwide (Reid et al. 2021). This risk is primarily driven by frequent heavy rainfall, tropical weather events, and rising sea levels. Consequently, governments at all levels face increasing pressure to maintain the local economy and stability of communities. Therefore, New Zealand’s government has progressively disclosed flood risk information to the public in recent decades (Glavovic, Saunders and Becker 2010; Montz 1993). However, despite the increasing accessibility and accuracy of flood risk information, a paradox still exists. We can still find that people's interest in purchasing properties in areas at risk of flooding has not diminished following the disclosure of such information. For example, this study found that in Hamilton City, the proportion of sales records within the floodplain remained stable over time. This trend remained stable across the 3-, 5-, and 8-years periods before and after the 2012 flood information disclosure, as well as the 2 years before and after the 2020 online flood map disclosure.[3] Meanwhile, the government's stance has indeed become increasingly cautious, generating and implementing more regulations related to the development of floodplains (Greater Wellington Regional Council 2022; Nguyen et al. 2019; Glavovic, Saunders and Becker 2010). However, building permits within the risk areas have not been prohibited in many cities. Newton (2024) reported that within one year after the significant flood in Auckland, 1,415 new permits were granted in flood risk areas.

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[3] Data source from transaction dataset purchased for the CoreLogic

To better understand New Zealand’s unique context, local researchers have adopted the combination of the Hedonic model and the DID method when studying the effects of flood risk information on housing markets (Nguyen et al. 2019; Nguyen et al. 2022; Filippova et al. 2020; Cheung and Yiu 2022). However, the results of these studies reveal intriguing findings. Nguyen et al. (2019) researched the discount effect after the flood event in Greater South Dunedin (GSD), focusing on how flood events influence property prices in designated MFL areas. Using the Hedonic, Difference-in-Differences (DID), and Difference-in-Difference-in-Differences (DDD) methods, this study analysed 29,481 transactions from January 2000 to September 2018 (including 4,380 records in the MFL area) and found that property prices experienced a discount ranging from 5.9% to 3.1%. This discount rate increased significantly to 7.8% following the 2015 flood event. This confirms results from many international studies that show actual flood events can exert a substantial impact on property prices. In 2022, Nguyen et al. (2022) extended this finding by examining how housing prices recovered after the actual flood event. The authors found that the sharp discount caused by the flood began to diminish within 15 months, with prices returning to pre-event levels. This aligns with Cheung and Yiu’s (2022) findings that while severe flood events led to minor and temporary price reductions events, they quickly faded as the market adjusted. Such patterns are consistent with international research, reinforcing the fading mechanism of the discount effect caused by flood events. Meanwhile, properties within MSL areas but outside the affected zones showed no significant price changes (Nguyen et al. 2019; Nguyen et al. 2022). This suggests that establishing MSL areas has effectively conveyed flood risk information to the public, and such regulation may help protect properties from physical damage during flood events. Consequently, the ability to be resilient to the event over time was built into the broader market.

However, not all studies in New Zealand align with international experience. For instance, Filippova et al. (2020) and Cheung and Yiu (2022) found minimal or no significant effects. Filippova et al. (2020) examined the introduction of sea level rise risk information into LIM reports in the Kapiti Coast. In 2012, the local council introduced this information, but the authors stated that it had an insignificant impact on the local housing market. Similarly, Cheung and Yiu (2022) investigated that published floodplain maps did not influence property prices in a high-value coastal suburb, Mission Bay, in Auckland. Because both study areas–Kapiti Coast and Mission Bay–are close to the coastline, these findings may suggest that high amenity values can somewhat mitigate the effects of flood risk information on properties (Chen, Li and Hua 2019).

Furthermore, Filippova et al. (2020) highlighted another intriguing consequence of publishing flood risk information. They found that a strong dissatisfaction among homeowners was triggered after announcing sea level rise (SLR) risk information, although there was no significant discount effect in the local housing market. Following a series of legal actions, the local council removed related information from the LIM report in October 2014. The decision was based on a judicial ruling stating that, “the lines were starkly simplistic as a summary of the complex Shand information and have the potential to seriously affect the value and marketability of coast properties.” (Filippova et al. 2020, 8)

These New Zealand findings suggest that disclosing flood risk information may not always decrease housing prices. This phenomenon is particularly relevant to this study, as it raises the question of whether and to what extent local housing markets incorporate risk information into decision-making. Meanwhile, while all four studies accepted the combination of Hedonic and DID methods, there is an inherent heterogeneity issue (Banzhaf 2021). This further motivates this research to explore flood risk information more comprehensively by employing additional methods.

3 Methodology

3.1 Research Area

As previously mentioned, this study focuses on Hamilton City as the research area. Situated in the north-central region of New Zealand's North Island, it serves as the economic and administrative hub of the Waikato region. The iconic Waikato River flows through the city from south to north, along with several scattered lakes of varying sizes.

There are several reasons for selecting Hamilton City. First, it is an inland city, whereas most studies on the effects of published flood risk in New Zealand focus on coastal areas. In these areas, flood risks are more likely to be driven by coastal events, sea-level rise, and heavy rainfall (Nguyen et al. 2002; Filippova et al. 2020; Cheung and You 2022). However, as an inland city, Hamilton is not directly threatened by hurricanes, storms, or rising sea levels. This may eventually give the local council and individuals a different angle when considering and managing flood risk information compared to their coastal counterparts (Pommeranz and Steininger 2020; Bin et al. 2008). A key distinction is that, as indicated by Pommeranz and Steininger (2002), the frequency of flood events in inland areas is lower than in coastal areas. This may result in a lower perceived risk of flooding, resulting in reduced public awareness of existing flood hazards. Therefore, a study that offers sufficient support for Hamilton’s local council to understand buyer responses in the housing market is urgently needed.

Secondly, Hamilton City Council provides comprehensive flood risk information data to support this study. Although most regional and territorial councils have made flood risk information available online (Walsh et al. 2019), gathering comprehensive details remains challenging. When this study was initially intending to conduct a nationwide analysis that included all major cities, it was found that while many councils had released online maps, the level of detail provided was often insufficient. On one hand, not all local councils have published similar flood risk information. City councils such as Auckland, Hamilton, and Wellington published more than one kind of information, whereas others, like Invercargill and New Plymouth, only released limited information. This inconsistency posed a challenge for this research in establishing a clear standard for determining whether a property is located within the officially designated flood risk zones. For example, in Hamilton, properties in some areas could be located in 1-in-100-year Flood Extent areas but not in 1-in-100-year Flood Hazard areas (Hamilton City Council 2024). Furthermore, councils may not always provide downloadable datasets for published information. Efforts were made to contact various councils to request the relevant datasets; however, due to the limited timeframe of this project, it was not possible to obtain all the necessary data.

More importantly, Hamilton City Council supports this study with a detailed timeline about how flood risk information was disclosed. To meet the objectives of this research, it is essential to have a clear timeline of when flood risk information was released and updated to the public. However, most councils do not publish such detailed timelines online. Some only indicate the upload and last update dates for their downloadable datasets; unfortunately, such information is insufficient for this research. This limitation arises because a single dataset may undergo multiple updates. For instance, Hamilton's Floodviewer platform continued to launch updates until late 2024 (Hamilton City Council 2024). Without a precise timeline, it becomes challenging to determine whether a transaction occurred before or after the disclosure of flood risk information. Fortunately, Hamilton City Council (2024) provided a comprehensive timeline detailing when and on which platforms flood risk information was made publicly accessible. This information is crucial for this research and serves as a key reason for selecting Hamilton City as the research area. The availability of such data is instrumental in establishing a standard for determining a property's flood risk status and identifying the temporal relationship between a transaction and the disclosure of flood risk information.

3.1.1 Geographic and Urban Context

Hamilton experiences more stable weather conditions compared to most coastal areas in New Zealand (Waikato Regional Council 2023). Geographically, the city is located on a relatively flat plain. The western, northern, and south-eastern parts have relatively higher elevations (50–100 meters), while central and waterfront areas along the Waikato River have relatively lower elevations (20–40 meters), as illustrated in Figure 1 (Topographic Map of Hamilton 2024). This elevation difference may lead to more concentrated water accumulation in low-lying regions during heavy rainfall events.

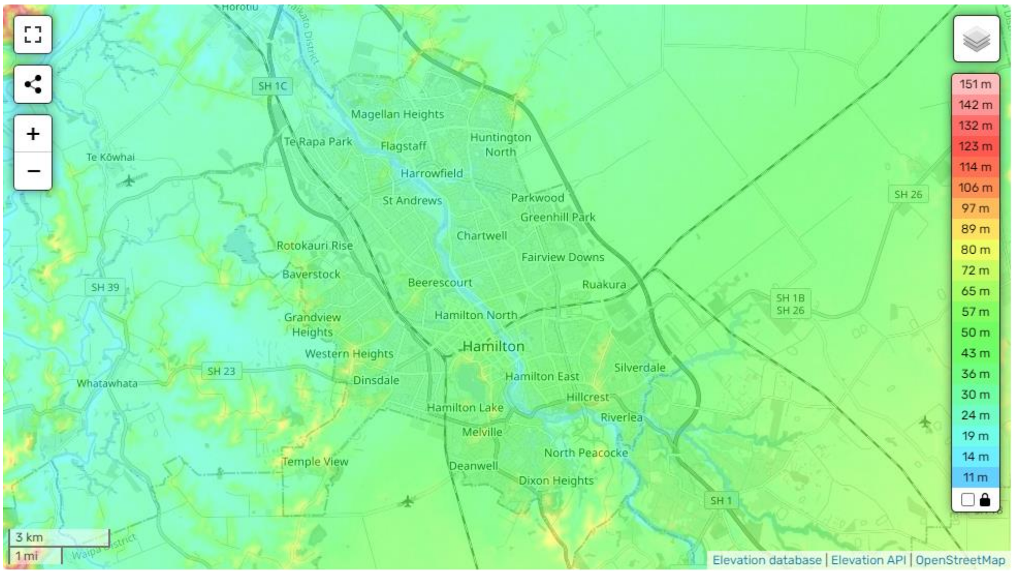


Figure 1: Topographic Map of Hamilton 2024. Source from https://en-nz.topographic-map.com/map-vfhcz/Hamilton/?center=-37.77234%2C175.28618&zoom=12

The geographic features discussed above shape Hamilton's development patterns. The city gradually expanded from the low-lying flat areas, concentrating more resources and population in the city centre (Bowyer 2015; Hamilton City Council 2023a). Both old industrial zones, such as Frankton, and newer ones, including Te Rapa and its surrounding suburbs, are located in flat, low-lying areas (Hamilton City Council 2012). This spatial arrangement places a larger population and industrial zones at greater risk of inundation during heavy rainfall. Plan Change 12, which removes height limitations for residential buildings in the central area and other neighbourhood centres, continues to promote higher population density in low-lying areas (Hamilton City Council 2024). Simultaneously, Hamilton City Council's development strategy emphasises the growth of the urban central area (Hamilton City Council 2023a). These policies are likely to further intensify pressure on flood risk management efforts in Hamilton City.

3.1.2 Flood Risk Disclosure Evolution

These geographic features and development patterns inevitably increase the demand for effective flood risk management in Hamilton. As mentioned previously, under central government requirements, most regional and local authorities have published flood risk information to the public (Walsh, Paulik and Robertson 2019). Such risk information is an essential component of modern flood risk management, serving as a reminder of persistent risks, a reference for determining insurance premiums, and a tool for encouraging public participation (Pastor, Noy and Sin 2018; Dei-Tutu 2002; Walsh, Paulik and Robertson 2019). However, the extent and detail of published flood risk information vary across cities. This is because the central government only requires local authorities to shoulder the responsibility but does not enforce standardised requirements. Walsh, Paulik and Robertson (2019) indicated that this change occurred in the 1990s, leaving local governments to collect, generate, and publish relevant information based on their own technology and funding . Therefore, a well-resourced city is able to provide comprehensive data, while those with insufficient resources may struggle to supply necessary flood risk information.

Hamilton is one of the most well-developed and rapidly growing cities in New Zealand. A decade ago, the Hamilton City Council began disclosing flood risk information to the public. In 2012, the local council introduced a flood risk map identifying known 100-year floodplains in the latest district plan (Hamilton City Council 2012). As noted by the Hamilton City Council (Email communication with author, October 11, 2024), this map included floodplains in five catchments: Callum Brae, Hamilton East, Mangakootukutuku, Nawton, and Waitawhiriwhiri. Figure 2 shows all 100-year floodplains published in the

2012 District Plan. These floodplains are predominantly located in the low-lying areas mentioned in Figure 1, such as the urban central area and areas along the Waikato River. The old industrial zone was also covered. However, it is important to note that neighbourhoods excluded from the published floodplains are not necessarily free from flood risk. This is because in 2012, insufficient resources and technology led to only parts of the flood risk being measured, which resulted in this map. This, in turn, may have caused some homeowners to misinterpret the risk status of their properties, potentially resulting in mispricing (Gibson and Mullins 2020; Hino and Burke 2021).

This situation has evolved since 2020. Two significant advancements have been made, driven by increased resources and funding. First, the disclosing platform transitioned from paper-based reports to online maps. In 2020, Floodviewer was launched on the City Council's website (Hamilton City Council 2024). Compared to paper-based reports, this platform is much more accessible to the public. It allows individuals to view the latest flood risk information anytime and anywhere with an internet connection. Secondly, in addition to making the 2012 flood risk map available online, new maps covering additional catchments have been released. Table 1 shows the complete list of the history released by online maps. This list shows that until September 2024, flood risk information has been released for all suburbs in Hamilton City, as shown in Figure 3. The floodplains cover most low-lying areas, which confirms the previous statement that low-lying areas are more likely to be at risk of inundation. In addition to the floodplain, the Hamilton City Council has published other relevant information, such as the Overland Flow Path and the Flood Depression Areas (Hamilton City Council 2024). Although not all information has legal power or will be considered as a factor in the building industry, it serves as a valuable resource for individuals seeking to assess potential flood risks (Email communication with author, October 11, 2024).

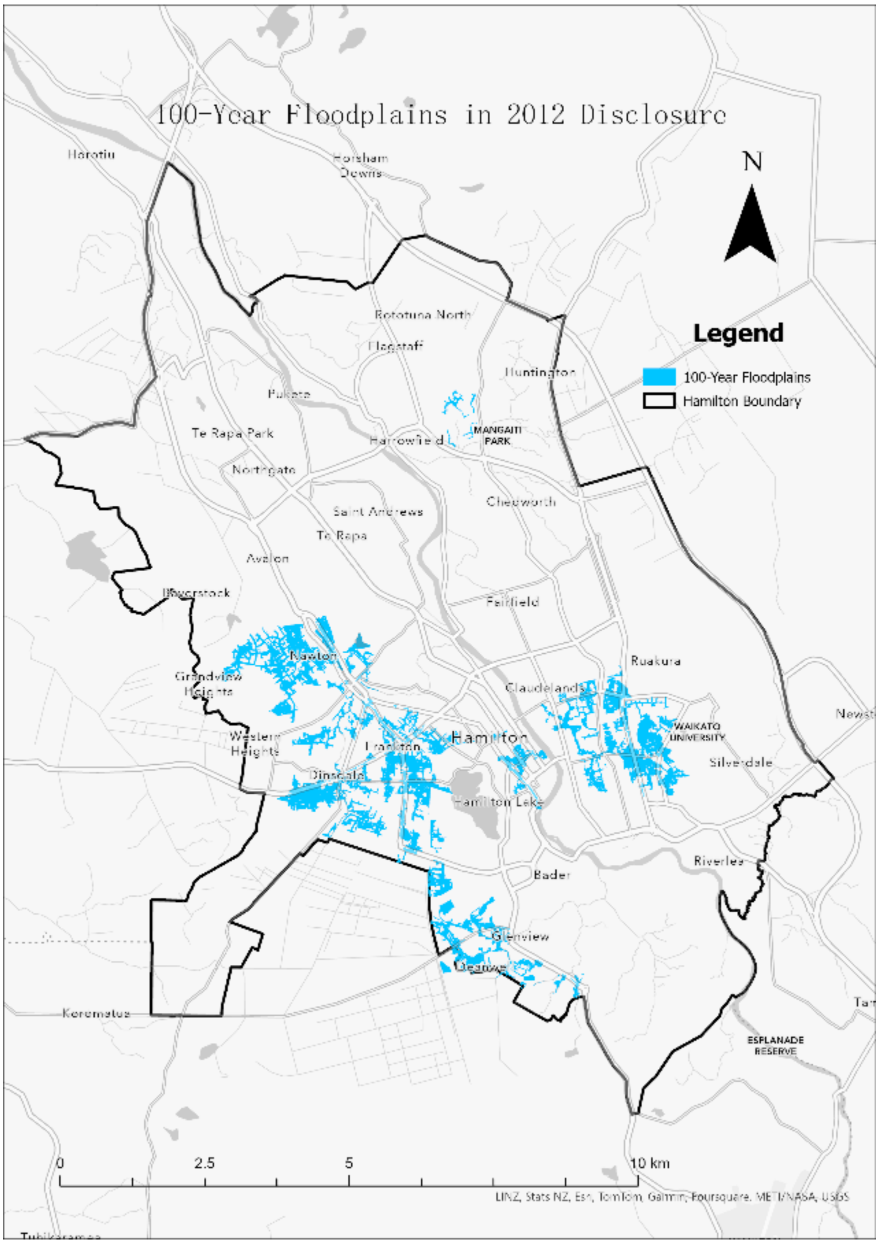


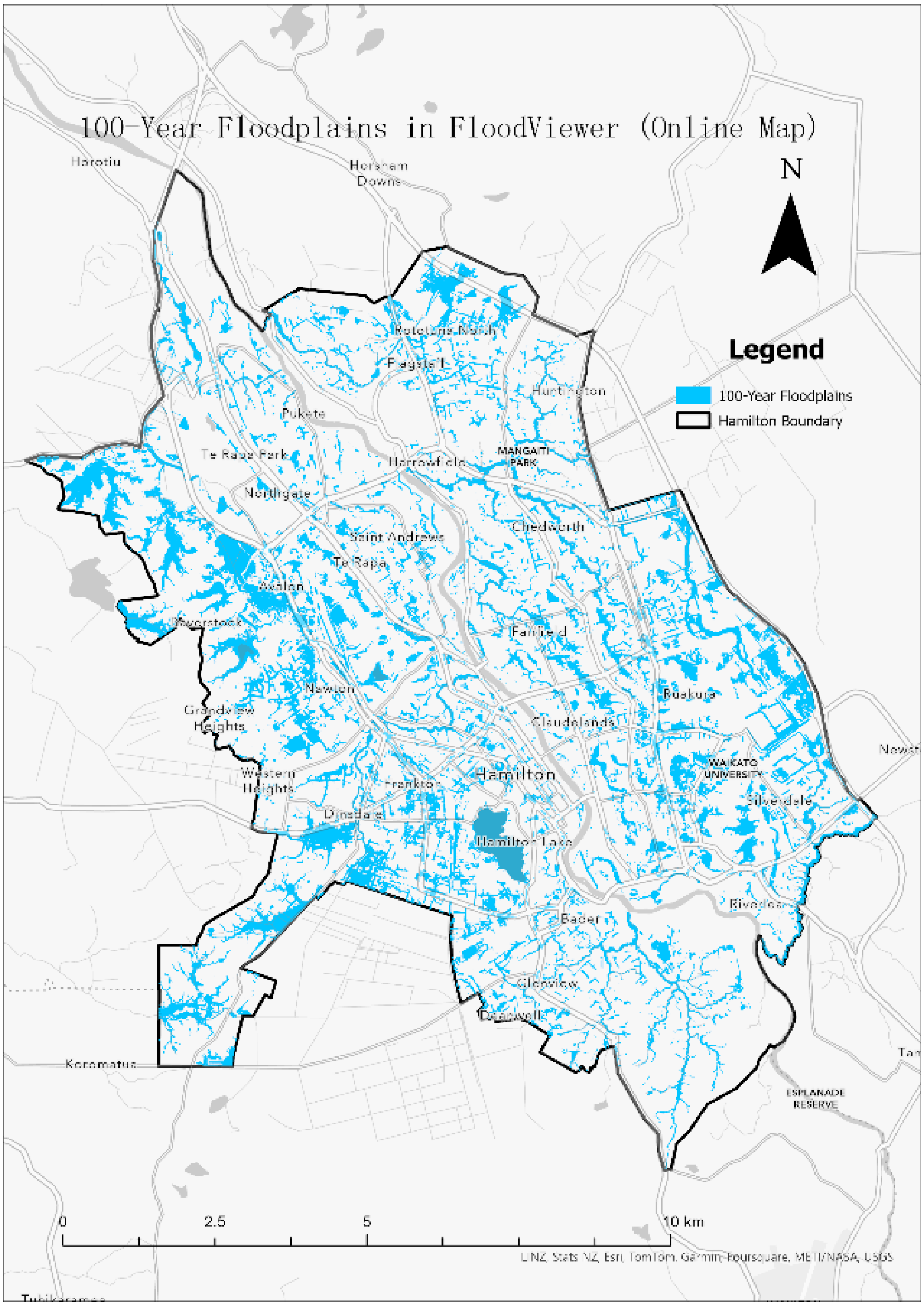
Figure 2: Hamilton 1-in-100-year floodplains announced in 2012 District Plan

The data source was acquired from Hamilton City Council via an email request.

Table 1: History of Floodviewer update.

Section	Description	Published/Updated catchments	Dates (public Floodviewer)
1.0	District Plan	Callum Brae, Hamilton East, Mangakootukutuku, Nawton, Waitawhiriwhiri	2012
2.0	Floodviewer Stage 1	District Plan Flood Hazard area, Mangakootukutuku, Rotokauri and Mangaheka	5 December 2020
3.0	Floodviewer Stage 2 - TAOK	TAOK	22 September 2021
4.0	Floodviewer Stage 2 – Te Rapa	Te Rapa	6 December 2021
5.0	Floodviewer Stage 2 – Waitawhiriwhiri	Waitawhiriwhiri	18 February 2022
5.1	Floodviewer Stage 2 – Waitawhiriwhiri additional letters	Waitawhiriwhiri	23 September 2022
6.0	Floodviewer Stage 3 – Kirikiriroa	Kirikiriroa	14 October 2022
7.0	Floodviewer Stage 3 – Nawton Mangakootukutuku Greenfield Flood extent	Nawton Mangakootukutuku (Peacocke)	6 December 2022
8.0	Floodviewer Stage 3 – OLFPs	Citywide	16 January 2023
9.0	Rapid Flood Assessment Data	Where detailed information is not yet available	Not displayed on public Floodviewer
10.0	Floodviewer Stage 3 – HamEast/Chartwell	Hamilton East/Chartwell	14 August 2023
11.0	Floodviewer Stage 3 – St Andrews	St Andrews	11 September 2023
12.0	Flood Depression	Citywide	4 March 2024
13.0	Floodviewer Stage 3 – Western Heights	Western Heights	2 September 2024

Note: The data source was acquired from Hamilton City Council via an email request.



LINZ, Stats NZ, Esri, TomTom, Garmin, Foursquare, METI/NASA, USGS

Figure 3: i-in-100-Year floodplains released on Floodviewer until September 2024.

The data source was acquired from Hamilton City Council via an email request.

3.1.3 Challenges and Constraints around Including Auckland

As previously discussed, this study initially focused on Hamilton City; however, efforts were made to expand the scope to include additional areas for a more comprehensive analysis. For example, in collaboration with the Auckland City Council, the Whau River catchment was considered as a potential supplementary study area. The Whau River catchment is located in the western part of central Auckland and consists mainly of single dwellings, making it comparable to Hamilton City. Including this area could facilitate a comparative analysis to determine whether coastal and inland urban areas exhibit similar responses to the disclosure of flood risk information.

However, transaction data in the Whau River catchment posed a significant challenge to this research. Since the floodplain map was uploaded and published to the public in 2020, only four years of transaction data (2018-2022) from the original database could be used. This limitation significantly constrains the sample size, especially for the Repeat-Sale model, which focuses only on properties in announced floodplains. Despite these challenges, Appendix A provides detailed information and regression results illustrating how the housing market in the Whau River catchment responds to flood risk information.

3.2 Data Collection and Preparation

3.2.1 Core Dataset

The transaction record is the most essential dataset for achieving the objectives of this study. This dataset was purchased from CoreLogic, a leading property data provider in New Zealand (CoreLogic New Zealand 2024). Initially, it contained over three million records, covering transaction records in New Zealand from January 1, 1990, to December 31, 2022. This dataset retains comprehensive property-related information, including location details, structural attributes, natural environment characteristics, and socioeconomic evaluations. This provides strong support for conducting regression analysis for this study.

In addition to transaction datasets, this research also incorporates other datasets to enhance reliability. These include spatial datasets and timelines for flood risk disclosures in Hamilton City. The first spatial dataset is the SA2 boundary map, downloaded from Stats.nz (2021). This GIS database contains the boundaries of all neighbourhoods in Hamilton, enabling the identification of whether a transaction occurred within a specific neighbourhood. The second geospatial dataset is the 1-in-100-year floodplains map, provided by Hamilton City Council. This process took more time than initially expected, as previously mentioned. This is because of the lack of detailed flood risk information in many city councils' online databases. Hamilton City Council has made extensive efforts to upload flood risk information across multiple platforms (Hamilton City Council 2024). However, not all published information holds legal authority. Ultimately, the council provided the necessary data, confirming that the 1-in-100-year floodplain map is the only one officially accepted as the standard to mark the flood risk status of any properties (Email communication with author, October 11, 2024).

Finally, the timeline for flood risk information disclosures is a critical component of this study, as such data is used to identify whether a transaction occurs after the disclosure of flood risk information. However, similar to flood maps, city councils in New Zealand have generally not published detailed records of their disclosure timelines. For instance, Hamilton City Council has noted that their online Floodviewer has been updated multiple times (Hamilton City Council 2024), but the timeline is not publicly available on its website. Fortunately, Hamilton City Council also provided this research with detailed updated records of floodplain maps, which were shown in Table 1.

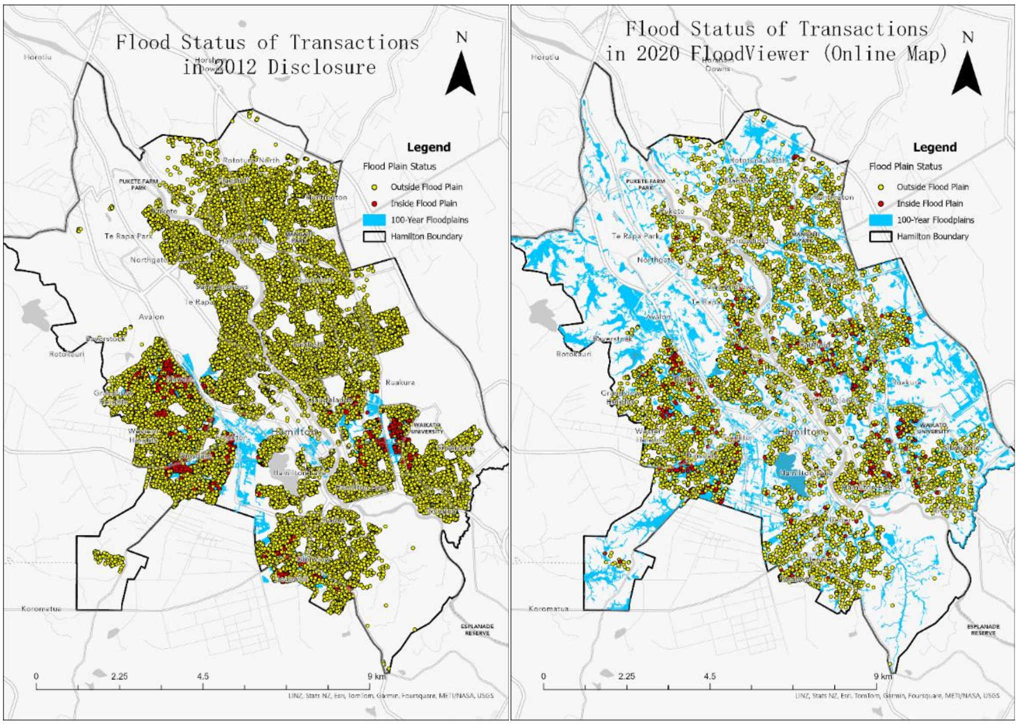
3.2.2 Data Processing

The data-cleaning process includes several key steps. First of all, by removing records lacking selling price, latitude, or longitude information, each data entry can be accurately geocoded in the Geographic Information System application. Next, all retained transactions are geocoded and compared with the SA2 boundaries to remove all records outside the selected study areas. After this fundamental process, most transactions were removed.

Then, the next step involves removing all records that do not meet the requirements. As this study aims to analyse how disclosure of flood risk information influences the local housing market, this necessitates focusing exclusively on freehold single-family residential properties, which dominate New Zealand's housing market (Reserve Bank of New Zealand 2024). Therefore, records with leasehold tenure and those not identified as single-family dwellings are removed from the dataset to ensure consistency in the analysis. Additionally, the timing of the flood risk information disclosure excludes sales records that were too distant in the past. Based on the previously mentioned time points for disclosing flood risk information in Hamilton, transaction records between 2004 and 2022 (excluding 2012, since the exact date of publishing the Hamilton District Plan is unknown) are accepted in this research. Such selection ensures that each significant time point has its own sub-dataset with symmetrical time intervals before and after the event. Finally, records with selling prices of no more than 100 NZDs, samples with missing values (NA) in the relevant variables (such as housing structural variables), and samples with a selling date before the building date are deemed incomplete and are removed.

The following step divides the remaining transactions into several groups and filters outliers. Since this study aims to analyse the effects of multiple flood risk information disclosures, grouping records based on the time points of each disclosure is very important. For the 2012 disclosure in Hamilton, records within 8 years before and after the disclosure are accepted. For the 2020 disclosure, only 2 years before and after the disclosure are selected, since the initial dataset only contains data until the end of 2022. This results in a panel dataset with 46862 transaction records for analysis of the 2012 disclosure and another panel dataset with 7155 samples for analysis of the 2020 disclosure in Hamilton. This study then adopts the 1.5 x IQR (Interquartile Range) method as the primary approach for outlier removal. This is a typical method for removing outliers. Frost (n.d.) explained that IQR is calculated as the difference between the first quartile (Q1) and the third quartile (Q3) of the entire dataset. 1.5 x IQR method means setting the lower bound as Q1 – 1.5 x IQR and the upper bound as Q3 + 1.5 x IQR. All data outside these two bounds will be considered outliers and removed. Although this method has largely ensured the robustness and reliability of the regression results, this study also applied the 3SD (Three Standard Deviations) and 1×IQR methods to remove outliers as a part of the robustness test to ensure maximum validity of the results. These will be explored in depth in the Result section.

After cleaning, spatial mapping is the final step of data processing. All transactions must be geocoded with the floodplain maps and need to be compared with the uploading timetable to identify the flood risk and post-disclosure status. Using the ArcGIS application, each remaining record was added with two extra variables: FP and PD. FP is equal to 1 if a property is located in the published floodplains and equal to 0 if otherwise. PD equals 1 if a transaction occurred after the flood risk information disclosure. Figure 4 shows the flood risk status of all transactions. Red spots indicate transactions in floodplains, and yellow spots indicate those outside this area. This map clearly shows that transactions within the announced floodplains account for a very small part of all transactions.



(a)Flood status of all properties in 2012 Disclosure (b)Flood status of all properties in 2020

Figure 4: Flood status of all properties in 2012 Disclosure and 2020 Floodviewer (Online Map)

3.2.3 Definition of Variables and Summary of Statistics

Initially, the raw dataset comprised over 60 variables. Through the aforementioned processes, the variables relevant to this research were naturally filtered out. These variables encompass core transaction characteristics, structural features of the properties, flood risk status, and post-disclosure status. Table 2 summarises the definitions and units of the variables utilised in this research.

Table 2: Definitions and Units of Variables Used in the Analysis

Variable	Meaning	Unit
Sale_Price	Transaction price of the property	New Zealand Dollars (NZD)
Building_Area	Floor area of building	Square meters (m^2)
Land_Area	Land area of property	Square meters (m^2)
View	Whether the property has a view	Binary (1 = Yes, 0 = No)
Modernisation	Whether the property is modernised	Binary (1 = Yes, 0 = No)
Built_Age	Age of the property at the time of sale	Years
QPID	Unique identifier for each property	Unique ID For identifying property
SA2	Statistical Area 2 code (neighbourhood ID)	Categorical Code
FP	Whether the property is located in a floodplain	Binary (1 = Yes, 0 = No)
PD	Whether the transaction occurred after the flood risk disclosure	Binary (1 = Yes, 0 = No)

Note: The data source was acquired from CoreLogic New Zealand.

The filtered dataset provides a comprehensive overview of the transactions included in the analysis. As a result, 26,745 properties were sold 46,862 times in total in 8 years before and after the 2012 disclosure. On average, the properties were sold for 413,565 NZD, aged 33.44, with an average building area of 130 m², a land area of 1,242.5 m², and 1.4 bathrooms per property. Furthermore, about 11.5% of properties were modernised before being put on the market, and 14.17% have a view.

For the 2020 online disclosure dataset, there were 7,155 transaction records involving 6,730 properties. It is evident that the selling frequency of the 2020 dataset is lower than that of the 2012 dataset. However, the 2020 dataset exhibits higher averages for key characteristics, including a selling price of 736,260 NZD, a building area of 142.89 m², a land area of 6,677 m², and a building age of 40.44 years. The proportions of properties having undertaken modernisation (11.5%) and those with a view (14.17%) remained relatively stable between the two datasets.

Based on this initial summary, the datasets will be further refined to meet the requirements of the DID model and the Repeat-Sale model utilised in this research. This segmentation will be carried out according to temporal and spatial characteristics, providing a detailed foundation for subsequent analysis. For the DID model, the sub-dataset for analysing Hamilton's 2012 flood risk information disclosure will be further segmented into three temporal groups: transactions within 3 years, 5 years, and 8 years before and after the publication of the 2012 Hamilton District Plan. Meanwhile, the dataset used to estimate the 2020 disclosure effects has not been further segmented. Table 3 summarises the variables' statistics across four time periods after applying the 1.5*IQR trimming method.

Table 3: DID Statistics for Key Variables Across Time Periods (1.5*IQR)

	3 years before and after 2012	5 years before and after 2012	8 years before and after 2012	2020 Online Disclosure
FP (Proportion)	0.047	0.050	0.052	0.06
PD (Proportion)	0.587	0.579	0.493	0.301
Sale_Price (mean)	359113.665	389738.196	387851.685	648836.6
Building_Area (mean)	129.234	128.595	127.798	138.156
Land_Area (mean)	735.700	648.453	1082.907	6921.570
View (Proportion)	0.140	0.138	0.134	0.132
Modernisation (Proportion)	0.103	0.109	0.112	0.125
Built_Age	34.475	34.512	33.508	40.62
Bathrooms (mean)	1.381	1.378	1.379	1.414
SA2 Count	61	62	62	60
Observation	15773	26637	45556	6857

Note: The data source was acquired from CoreLogic New Zealand.

From this table, there were 45,556 records in the 8 years before and after the 2012 disclosure (26,637 for 5 years and 15,773 for 3 years before and after 2012) and 6,857 records within 2 years before and after the 2020 publication. Around 5% of properties sold in each period were in floodplain areas. This indicates that properties in published floodplains had a similar appeal to buyers in different periods. For the 2012 disclosure, properties after the flood risk disclosure account for a huge part. Around half of the properties were sold after the flood risk disclosure. These are crucial phenomena that prompt this research to explore whether buyers in Hamilton consider flood risk status in their decisions. However, after 2020, only 29.9% of properties were sold after publication. This may be because not all parts of the online map were disclosed at the same time. For instance, risk information of catchments like the Te Rapa and TAOK was updated in the last Quarter of 2021. This leads to the periods before and after the disclosure not being evenly separated. Meanwhile, the mean selling prices in the 2020 dataset were noticeably higher than those in the 2012 dataset, reflecting the broader upward trend in housing prices (Quotable Value 2025). The average building area increased a little. In contrast, the average land area decreased significantly.

The Repeat-Sale model focuses exclusively on changes in sale prices for properties located within floodplains. Consequently, any record outside the floodplains is excluded from the analysis. Meanwhile, to examine the impact of disclosure on housing prices, this model includes only properties that were sold both before and after the disclosure within the specified time period. This undoubtedly will significantly narrow the dataset. Table 4 shows details of descriptive statistics used for the Repeat-Sale model after using the 1.5*IQR trimming method.

It is obvious that the Repeat-Sale model's observation is much lower than that of the DID model in any given time period, as expected. There were only 1173 records of 410 properties in 8 years before and after the 2012 disclosure (147 records of 71 properties in 3 years and 450 records of 191 properties in 5 years) and 22 records of 11 properties before and after the announcement of the 2020 online map. In all four different periods, around half of the transactions were sold after the risk disclosures. Compared to the DID model, the average sale prices are lower in the Repeat-Sale model. This means that selling frequency may not help to increase housing prices.

Table 4: Repeat Sale Statistics for Key Variable Across Time Periods （1.5*IQR）

	3 years before and after 2012	5 years before and after 2012	8 years before and after 2012	2020 Online Disclosure
PD (Proportion)	0.497	0.511	0.477	0.5
Sale_Price (Mean)	276354.2	305951.3	303156.3	597820.5
Built_Age (Mean)	39.1	38.78	37.02	49.05
Modernisation (Proportion)	0.088	0.091	0.073	0.091
SA2 Count	18	22	23	7
Observation	147	450	1173	22
QPID Count	71	191	410	11
Observation/QPID	2.07	2.36	2.86	2

Note: The data source was acquired from CoreLogic New Zealand.

3.3 Analytical Framework

As mentioned in the literature review section, the Hedonic model is widely used to research the effects of flood risk on housing prices. Atreya and Czajkowski (2014) indicate that "the component values of various attributes of heterogeneous goods are reflected in price differentials"(16). By incorporating a binary floodplain variable (FP), the model aims to assess how properties are affected by their geographic positioning within flood risk areas. However, since this model usually uses cross-sectional datasets (Malpezzi 2003), it is already unreliable for studying the causal effects in econometrics research (Hino and Burke 2021). This model commonly includes variables related to housing structure, environmental conditions, and flood risk factors (Atreya and Czajkowski 2014). Without controlling the time series and many other factors, this method is more likely to be biased (Hino and Burke 2021). For example, some studies clearly state that when studying flood risk effects, price reduction effects may result from many other factors instead of being exclusively due to being in the flood risk areas (Malpezzi 2003; Gabriel 1984).

To better understand how flood risk information influences housing prices, besides controlling socioeconomic and environmental factors, variables used to identify the price alteration after the specific time spots are more vital to this research. Therefore, this research uses the DID and the Repeat-Sale models to conduct a series of regression analyses. This choice assumes that stakeholders can (at least partially) respond rationally after receiving relative information (Hirshleifer 2015). Both models have the same binary variable PD to identify whether a transaction occurred after the disclosure. This variable is vital in helping this research understand how the market will revalue the property prices once the flood risk information is released.

Take the DID model in this research as an example. It assumes that without disclosing flood risk information, prices will not differ significantly between properties in flood risk areas and those outside (Hino and Burke 2021). By using an interaction variable, FP x PD, this model can effectively conclude whether the disclosure of flood risk decreases property prices if properties are located in the flood risk areas and are sold after disclosing. Although the Repeat-Sale model does not have a similar interaction variable with the DID model, it can still estimate the flood risk effect on properties in flood risk areas by exclusively focusing on those properties.

However, this study does not rely solely on the DID or Repeat-Sale model, as each approach presents certain limitations. The DID model may face challenges related to individual-level heterogeneity (Callaway 2022). This means that it cannot eliminate the influences from unobserved individual differences. Imbens and Jeffrey (2009) indicate that unobserved individual differences are an issue that all researchers have to confront when estimating causal effects. This means that although the DID model has included some structural and environmental variables, the estimates may still be biased. Fortunately, this issue can be overcome by introducing the Repeat-Sale model. By focusing on individual samples over time, interferences associated with different housing characteristics between various properties will be excluded. Meanwhile, as Lamond, Proverbs and Hammond (2010) point out, the Repeat-Sale model suffers from low credibility with a restricted sample size caused by strict sample selection criteria; however, combining it with the DID approach can help provide more robust support. The combination of DID and Repeat-Sale models can provide a robust mechanism to analyse market dynamics in both global trends and at individual levels. While the DID model relies on a larger dataset and reveals broader market patterns, the Repeat-Sale model focuses on individual properties by isolating interferences among various samples to ensure precision. Together, this framework is robust in analysing the effects of flood risk disclosure exerted on housing markets.

3.3.1 Difference-in-Differences (DID) Model

This method will classify samples into two groups: the treatment group and the control group. It assumes that without any treatment, there will be no differences between the trends of these two groups. This Parallel Trends Assumption is essential to the DID model (Angrist and Pischke 2008). In this study, the disclosure of flood risk information is the treatment event. All transactions are then automatically separated into a treated group (located in the published floodplains and marked as 1) and a control group (located outside the published floodplains and marked as 0). Meanwhile, pre- and post-treatment dynamics are also vital to the DID analysis (Cerulli 2015). This required that all transactions be classified as pre-treatment group and post-treatment group based on whether the timing of the sample was before or after the treatment event. In this study, transactions that occurred before the disclosure of flood risk will be grouped into the pre-treatment group (marked as 0), and those that occurred after the disclosure will be in the post-treatment group (marked as 1).

Therefore, the most important variable in the DID model is the interaction variable of the treatment and post-treatment groups. This variable is essential to the study, because it can capture the treatment effect (Cerulli 2015; Angrist and Pischke 2008), as it represents the additional effects for the treatment group after the treatment event. In this study, this variable equals 1 for those transactions that occurred after the flood risk disclosure and in the published floodplains, and 0 otherwise. By estimating the coefficient of this variable, this model effectively investigates how disclosing flood risk information influences housing prices for different groups and isolates the causal effects by accounting for group-specific and unchanging factors (Bertrand, Duflo and Mullainathan 2004).

The DID model in this study is given by equation (1)

$$\log(\Pr i\, ce_{it}) = \beta_0 + \beta_1 \cdot FP_i + \beta_2 \cdot PD_t + \beta_3 \cdot (FP_i \times PD_t) + \lambda \cdot Z_{it} + \eta_q + \alpha_{SA2Y} + \varepsilon_{it} \quad (1)$$

The independent variable is the natural logarithm of the sale price for property i at time t. In this study, the group-specific factor is FP. A property is marked as “1” if it is located in an announced 1-in-100-year floodplain and considered as “treated.” Otherwise, properties will be considered as belonging to the control group if they are outside the floodplain and marked as "0." β_1 captures the price effects of being located in or out of the floodplain. The unchanging factor is whether a transaction happened before or after the disclosure. PD is the variable used in this research to identify this factor. All transactions are marked as "1" if they occurred after disclosing flood risk information, while others are marked as "0." β_2 represents general housing price changes before or after the flood risk information disclosure. β_3 is the coefficient of the interaction variable. It captures the price effects after the disclosure of flood risk (treatment), specifically for properties located within the 1-in-100-year floodplain (treated group).

Variable Z represents property-specific characteristics, including Building Floor Area, Land area, View Type, Modernisation, Bathrooms, and Building Age at the selling time t. η_q refers to the seasonal fixed effects, which help absorb seasonal and cyclical fluctuations commonly observed in housing markets. For example, Rossini (2000) found that seasonal variations are prevalent across various suburbs in Adelaide, Australia. Therefore, controlling this effect ensures that estimations are free from seasonal distortions. α_{SA2Y} is an interaction of Statistical Area 2 (SA2) and the Sale Year of the specific property. In New Zealand, SA2 is a geographic hierarchy often used as a statistical standard. It usually contains 1000 to 4000 residents (Stats NZ 2022). According to the historical and current District Plan (Hamilton City Council 2012; Hamilton City Council 2023b), different SA2s have not been evenly developed over time. Meanwhile, with a long history, various SA2s have inherent differences, including imbalances in educational, medical, and economic resources, which can influence housing prices. Introducing α_{SA2Y} can help to account for the interference of temporal and spatial factors at the same time.

However, while providing a broad perspective, the DID model still has its inherent limitations: the heterogeneous issue (Caetano and Callaway 2024; de Chaisemartin and D'Haultfoeuille 2022), as mentioned above, is one. Although this study uses fixed effects to isolate interference, some unobserved differences at the individual level may not be successfully accounted for in this model. Therefore, to conduct more reliable research, this study also uses the Repeat-Sale model, which is mostly free free from the influence of individual differences.

3.3.2 Repeat-Sale Model

This model perfectly meets the need of this study to solve the heterogeneous issue in the DID model. Bailey, Muth and Nourse (1963) first introduced and discussed the core concept of this model. It focuses on those properties sold at different times and treats housing characteristics as unchanged factors, while assuming no significant depreciation or alteration over time. This effectively avoids price fluctuations caused by differences in housing characteristics. Therefore, it is commonly used to estimate whether a specific event can influence housing prices or not (Grimes and Young 2010). By thoroughly dividing the samples into two groups based on whether they occurred before or after the specific event, the effects of the event can be effectively estimated.

As mentioned above, the specific event in this study is the disclosure of flood risk. Properties located in the published 100-year floodplains are then automatically divided into Group 1, which includes those sold after the disclosure and marked as 1, and Group 2, which includes those sold before the disclosure and marked as 0. This method absorbs the effect of those unchanged property characteristics by focusing on repeated transactions and provides a robust framework to isolate price changes driven by flood risk disclosures. However, one thing that should be noted here is that in this study, the Repeat-Sale model focuses on properties in floodplains only. This is because this research aims to explore how flood risk disclosure impacts the prices of properties clearly identified as being at high risk of flood events.

The Repeat-Sale model is given by equation (2)

$$\log(\mathrm{Pr}\,ice_{it}) = \theta_0 + \theta_1 PD_{it} + \theta_2 Modernisation_{it} + \gamma_t + \alpha_i + \varepsilon_{it} \quad (2)$$

The meaning of most variables is similar to the DID model variable. For example, the independent variable is the natural logarithm of the sale price for the property i at time t. PD_{it} is the indicator variable. If the sale occurs after the risk disclosure it equals 1 and is 0 otherwise. Modernisation is the only characteristic of housing that is not accounted for by the fixed effect of the individual property. This is because, after looking at the dataset in-depth, this study found that some owners may not always renovate their property over time. It equals 1 if the property is renovated before the sale and 0 otherwise. γ_t is the fixed effect for the year of sale. α_i is the property-specific fixed effect that controls those unchanged characteristics. This ensures that property-specific characteristics and time-varying factors are accounted for, thus minimising biases caused by unobserved heterogeneous characteristics.

However, the limitation of this model is also apparent. In any local housing market, not all properties are sold more than once. By setting additional filtering criteria, the number of transaction records available for regression analysis will be further reduced. This means that the Repeat-Sale model undoubtedly leads to a much smaller sample size, as it only focuses on those properties with selling records both before and after the flood risk disclosures, which may result in sample selection bias (Belanger and Bourdeau-Brien 2017; Hino and Burke 2021). In this research, the number of Repeat-Sale samples only accounts for less than 3% of the total database.

3.3.3 Justifications

The reasons for selecting the DID model and the Repeat-Sale model in this research are their robustness and reliability. Firstly, these two models are complementary to each other. The DID model includes a significantly larger sample size but has an inherent weakness in having no ability to deal with the heterogeneous issue at the individual level. In contrast, by focusing on the same properties, the Repeat-Sale model can compensate for this limitation, while the DID model can offset its limited sample size. The combination of the DID model and the Repeat-Sale model provides robust support for this research's overall stability and reliability.

Secondly, independent variables in these two models are essential to this study. Whether or not to include a variable significantly shapes the final estimation and may potentially introduce the sample selection bias (Heckman 1979). For the DID model, besides the core variable $FP_i \times PD_t$, this study incorporates many property characteristics provided in the initial dataset as independent variables to ensure a comprehensive analysis. The root of this selection is that the DID model cannot eliminate the impact of individual-level differences. For the Repeat-Sale model, besides the core variable PD_{it}, Modernisation also stands out as a critical independent variable. This is because such characteristics vary depending on the behaviour of property owners. Unlike other structural characteristics, this cannot remain constant over time and is absorbed by the fixed effects. Ignoring this variable may also introduce unnecessary bias.

Finally, those selected fixed effects are essential to this study. By controlling related variables, these fixed effects effectively absorb the interferences resulting from the seasonal, temporal, and spatial variations. This ensures that unobserved characteristics minimally influence the estimations in this study, enhancing the accuracy and reliability of the results.

4. Results

Changes in housing prices are always considered as a reference for evaluating whether participants effectively receive and account for such information in decision-making processes (Cheung and Yiu 2022; Gibson and Mullins 2020). With the council providing more detailed and accessible flood risk information to the public, it is a natural expectation that the public is correctly receiving the relevant information and taking corresponding actions in response. However, the findings of this research suggest that buyers in the Hamilton housing market have not sufficiently adjusted their purchasing decisions in response to the disclosure of flood risk information, whether through the 2012 District Plan or the 2020 online maps. The DID model results indicate that within an 8-year window around the 2012 disclosure, properties in flood-prone areas experienced a slight price decline of 1.6%, which is statistically significant at the 0.05 level. However, no significant price change was observed following the 2020 update, where the estimated effect was a 2.1% decrease. Meanwhile, the Repeat-Sale model, focusing on properties in flood risk areas, shows significant positive effect following the disclosures, with a 114% impact for 2012 and 10.2% for 2020.

4.1 Results for Difference-in-Difference Model

The interaction variable FP x PD serves as the focal point in the DID model. It captures the broader and overarching price-change trends of properties located in the published floodplains in terms of the influence of disclosing relevant risk information. Table 5 presents the detailed estimations for FP x PD along with all other variables in the DID model across all time periods (Using the 1.5*IQR trimming method for Hamilton's dataset). It is noted that PD is omitted in the 2012 fixed-effects regressions, because it is a binary variable indicating whether the sale occurred after 2012. This variable is perfectly collinear with time-fixed effects when the model accepts the intersection of SA2 and Sale Year as a fixed effect and cannot be estimated separately.

Table 5 DID Results for Disclosure Periods (1.5*IQR)

	3 years before and after 2012 (SE)	5 years before and after 2012 (SE)	8 years before and after 2012 (SE)	2020 Online Disclosure (SE)
FP x PD	0.009 (0.008) n.s.	0.018 (0.010) n.s.	0.016 (0.004)*	-0.021 (0.028) n.s.
FP	-0.031 (0.009)*	-0.039 (0.011)*	-0.031 (0.007)*	0.001 (0.008) n.s.
PD	Omitted	Omitted	Omitted	0.028 (0.011) n.s.
Building_Area	0.004 (0.000)***	0.003 (0.000)***	0.003 (0.000)***	0.002 (0.000)***
Land_Area	0.000 (0.000)*	0.000 (0.000) n.s.	0.000 (0.000) n.s.	-0.000 (0.000) n.s.
View	0.101 (0.004)***	0.098 (0.004)***	0.100 (0.001)***	0.017 (0.010) n.s.
Modernisation	0.080 (0.003)***	0.080 (0.003)***	0.084 (0.003)***	0.072 (0.006)**
Bathrooms	0.090 (0.002)***	0.088 (0.002)***	0.072 (0.007)**	0.047 (0.008)*
Built_Age	-0.001 (0.000)**	-0.001 (0.000)*	-0.001 (0.000)**	0.000 (0.000)*
Quarter	Controlled	Controlled	Controlled	Controlled
SA2_Year	Controlled	Controlled	Controlled	Controlled
Observation	15773	26637	45556	6857
A-R2	0.719	0.741	0.807	0.713

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant.

For the 2012 disclosure event, the coefficients for FP x PF are positive across all time periods (0.009 for the 3-year sub-dataset, 0.018 for the 5-year sub-dataset, and 0.016 for the 8-year sub-dataset). Notably, only the result for the 8-year period is statistically significant at the 0.05 level, while the values for the other two periods are not significant. This suggests that the Hamilton Council's attempt to disclose flood risk information in the 2012 District Plan failed to stop property price growth in both the short and long terms. Buyers may ignore or not receive such information during the decision-making process when purchasing a property. This phenomenon has not changed after the launch of Floodviewer in Hamilton City in 2020. Although the coefficient of the interaction variable FP x PD switched to negative (-0.021), it remains insignificant. Figure 5 clearly illustrates this trend.

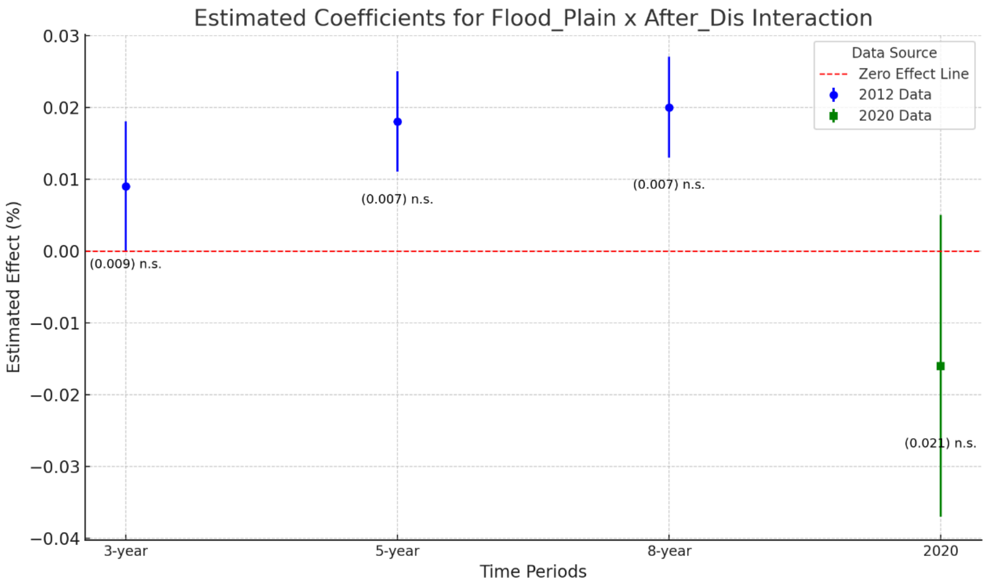


Figure 5: DID Results for FP x PD Interaction (1.5 IQR)

Note: The estimated effects represent the coefficients of the interaction term FP x PD from the DID model.

While the 2012 and 2020 disclosures shared the goal of informing the public about flood risks, their methods and scope differed significantly. These differences are evident in two key aspects. Firstly, the 2020 online disclosure retained the floodplains announced in the 2012 Hamilton District Plan without any modifications while introducing new floodplains in previously uncovered areas. Secondly, the platform for disclosing flood risk information has switched from traditional paperwork to an online platform. Under such situations, the slightly changing coefficient of FP x PD indicates that, in Hamilton City, new flood risk information may be failing to capture buyers' attention in any time period. Moveover, exclusively updating disclosure technology to a more easily accessible method (online platform) in Hamilton City may not be effective in changing how change how the market perceives the information around relative risks.

However, unlike the marginal effects of FP x PD, most of the other variables significantly influence housing prices. In Hamilton, for nearly two decades, housing characteristics and the surrounding environment have continued to play a major role in determining property values. The Building Area has a slightly positive and highly significant influence on housing prices, whereas the Land Area shows no measurable effect. This may partly explain the upward trend in Hamilton City's average building area and the downward trend in its average land area, as discussed in the research area section. Both the number of bedrooms and pre-sale modernisation have significant and positive effects across all time periods. However, having a view significantly increases housing prices only in the results of the 2012 disclosure, with no significant effect observed in the 2020 disclosure.

4.2 Results of the Repeat-Sale Model

Similar to the interaction variable FP x PD in the DID model, PD emerges as the most critical variable in the Repeat-Sale model of this study. Since, in this model, the potential samples only include records located in the published floodplains, the PD can effectively capture how prices change after the disclosure. Table 6 provides the detailed estimations for PD alongside other variables in the Repeat-Sale model, using the 1.5*IQR trimming method applied to Hamilton's dataset across all time periods.

Table 6: Repeat Sale Results for Disclosure Periods (Using 1.5 IQR)

	3 years before and after 2012 (SE)	5 years before and after 2012 (SE)	8 years before and after 2012 (SE)	2020 Online Disclosure (SE)
PD	0.184 (0.033)***	0.418 (0.021)***	1.140 (0.023)***	0.102 (0.000)***
Modernisation	Omitted	0.147 (0.044)**	0.155 (0.032)***	Omitted
Observation	147	450	1173	22
A-R²	0.883	0.884	0.894	0.947
Sale_Year	Controlled	Controlled	Controlled	Controlled
QPID	Controlled	Controlled	Controlled	Controlled

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant.

Modernisation was omitted in the 3-year and 2020 models due to collinearity with fixed effects.

This table clearly demonstrates that the coefficients of PD are positive and statistically significant at the 0.001 level across all four periods. This means that disclosing flood risk information did not achieve the intended effect at any period in the recent two decades in Hamilton. This also supports the DID model's conclusion that this information was not taken into account when the market determined housing prices Instead, the coefficient of this variable in the 2012 disclosure keeps increasing when a more extended study period is chosen (0.184 for 3 years before and after the disclosure, 0.418 for 5 years, and 1.140 for 8 years). This increasing number suggests that, with the passing of time, the housing price of the same property will climb more dramatically. This phenomenon aligns with the overall increasing trend of housing prices in Hamilton, as mentioned in the data section. Figure 6 illustrates these results.

Figure 6: Repeat Sale Results for Disclosure Periods (1.5 IQR)

For other variables, most of the housing character variables have been absorbed by the fixed effect QPID, except Modernisation. Coefficients of this variable in the Repeat-Sale model indicate that property renovation can also increase housing prices, which is the same as the DID model's results. However, in the periods 3 years before and after the 2012 disclosure and before and after the update of the 2020 online maps, this coefficient was omitted automatically. This may be due to collinearity with QPID in these two periods, suggesting a higher likelihood of observing similar decisions among buyers within a short time frame.

4.3 Robustness Test

To ensure the validity of the result, this research used different trimming methods to examine the sensitivity of the model to data pre-processing techniques. These different trimming methods include Three Standard Deviations (3SD) and One Time the Interquartile Range (1 * IQR). In this research, the dataset includes extreme outliers, such as a property sold for 350,000,000 NZDs. These outliers significantly inflate the standard deviation, which in turn widens the gap between the upper and lower bounds defined by the 3SD method. This makes the 3SD method less stringent compared to the 1.5*IQR method. Meanwhile, it is evident that 1*IQR is a more rigorous way to remove outliers than 1.5*IQR. The direct result of these differences is that the sub-dataset trimmed by 3SD contains more observations (46,860 in 8 years before and after the 2012 disclosure) than that trimmed by 1*IQR (43,950 in the same period). Tables 7 and 8 show detailed results using these two trimming methods.

Table 7: DID Results for Disclosure Periods (3SD)

	3 years before and after 2012 (SE)	5 years before and after 2012 (SE)	8 years before and after 2012 (SE)	2020 Online Disclosure (SE)
FP x PD	0.009 (0.009) n.s.	0.018 (0.007) n.s.	0.020 (0.007) n.s.	-0.016 (0.021) n.s.
FP	-0.028 (0.009) *	-0.035 (0.010) *	-0.028 (0.007) *	0.006 (0.006) n.s.
PD	Omitted	Omitted	Omitted	0.034 (0.013) n.s.
Building_Area	0.004 (0.000) ***	0.004 (0.000) ***	0.003 (0.000) ***	0.003 (0.000) ***
Land_Area	0.000 (0.000) n.s.	0.000 (0.000) n.s.	0.000 (0.000) n.s.	0.000 (0.000) n.s.
View	0.116 (0.006) ***	0.116 (0.005) ***	0.120 (0.003) ***	0.030 (0.010) n.s.
Modernisation	0.085 (0.005) ***	0.085 (0.005) ***	0.088 (0.004) ***	0.081 (0.007) **
Bathrooms	0.099 (0.002) ***	0.096 (0.003) ***	0.080 (0.008) **	0.045 (0.011) *
Built_Age	-0.001 (0.000) **	-0.001 (0.000) **	-0.001 (0.000) **	0.001 (0.000) *
Quarter	Controlled	Controlled	Controlled	Controlled
SA2_Year	Controlled	Controlled	Controlled	Controlled
Observation	15,924	27,129	46,860	7,152
A-R2	0.721	0.748	0.813	0.724

Note: * p < 0.05, ** p < 0.01, *** p < 0.001, n.s. = not significant.

Table 8: DID Results for Disclosure Periods (1*IQR)

	3 years before and after 2012 (SE)	5 years before and after 2012 (SE)	8 years before and after 2012 (SE)	2020 Online Disclosure (SE)
FP x PD	0.009 (0.008) n.s.	0.016 (0.011) n.s.	0.018 (0.005) *	-0.006 (0.014) n.s.
FP	-0.032 (0.008) *	-0.035 (0.008) *	-0.030 (0.004) **	-0.002 (0.009) n.s.
PD	Omitted	Omitted	Omitted	0.027 (0.008) *
Building_Area	0.004 (0.000) ***	0.003 (0.000) ***	0.003 (0.000) ***	0.002 (0.000) ***
Land_Area	0.000 (0.000) *	0.000 (0.000)	0.000 (0.000) n.s.	0.000 (0.000) n.s.
View	0.093 (0.003) ***	0.089 (0.003) ***	0.093 (0.002) ***	0.019 (0.008) n.s.
Modernisation	0.079 (0.003) ***	0.078 (0.003) ***	0.082 (0.002) ***	0.069 (0.004) ***
Bathrooms	0.088 (0.002) ***	0.087 (0.002) ***	0.071 (0.007) **	0.044 (0.006) **
Built_Age	-0.001 (0.000) **	-0.001 (0.000) **	-0.001 (0.000) **	0.000 (0.000)
Quarter	Controlled	Controlled	Controlled	Controlled
SA2_Year	Controlled	Controlled	Controlled	Controlled
Observation	15,611	25,990	43,950	6,629
A-R2	0.714	0.736	0.799	0.72

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant.

These two tables demonstrate that, besides slight changes in numerical values, the positive or negative signs of coefficients and significance of most coefficients did not change while shifting trimming methods. One subtle exception is the result of the DID model for 8 years before and after the 2012 disclosure when using the 3SD method. Its significance changes from 0.05 (1.5*IQR and 1*IQR) to insignificant (3SD). The reason for this difference lies in the relatively permissive approach of the 3SD method in the context of this research.

For the Repeat-Sale model, the results from the 3SD and 1*IQR trimming methods reveal a similar pattern to the robustness test of the DID model, although with even smaller variations. The increase or decrease in the number of observations only has slight variations. For example, in the original 1.5*IQR sub-dataset, there are 1173 transactions in the 8 years before and after the 2012 disclosure. In the 3SD and 1*IQR sub-dataset, the observations are 1178 and 1164, respectively. As a result, the coefficients for PD remain virtually unchanged across all sub-datasets, with their significance consistently stable regardless of the trimming methods applied. Table 9 and Table 10 show the detailed results of the Repeat-Sale model using 3SD and 1*IQR data cleaning methods.

Table 9: Repeat Sale Results for Disclosure Periods (3SD)

	3 years before and after 2012 (SE)	5 years before and after 2012 (SE)	8 years before and after 2012 (SE)	2020 Online Disclosure (SE)
PD	0.184 (0.033)***	0.418 (0.021)***	1.145 (0.023)***	0.102 (0.000)***
Modernisation	Omitted	0.147 (0.044)**	0.154 (0.032)***	Omitted
Observation	147	450	1178	26
A-R²	0.883	0.884	0.889	0.978
Sale_Year	Controlled	Controlled	Controlled	Controlled
QPID	Controlled	Controlled	Controlled	Controlled

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant.

Table 10: Repeat Sale Results for Disclosure Periods (1*IQR)

	3 years before and after 2012 (SE)	5 years before and after 2012 (SE)	8 years before and after 2012 (SE)	2020 Online Disclosure (SE)
PD	0.184 (0.033) ***	0.419 (0.021) ***	1.135 (0.023) ***	0.102 (0.000) ***
Modernisation	Omitted	0.147 (0.044) **	0.150 (0.033) ***	Omitted
Observation	147	448	1,164	22
A-R²	0.883	0.881	0.921	0.947
Sale_Year	Controlled	Controlled	Controlled	Controlled
QPID	Controlled	Controlled	Controlled	Controlled

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant.

These findings confirm that the overall results are stable across different outlier-trimming methods, with minimal numerical variation. The only difference in the 8-year DID model using the 3SD method highlights the importance of considering the characteristics of each trimming approach. Notably, having a relatively permissive nature to the trimming approach may allow unexpected extreme outliers to exist in the potential dataset. This may weaken the statistical significance of specific coefficients.

More importantly, it is demonstrated that this research's findings align with New Zealand research in that some studies indicate that publishing flood risk information cannot effectively influence housing markets (Cheung et al. 2022; Filippova et al. 2020). This consistency highlights that this phenomenon is prevalent across coastal and inland urban areas in New Zealand. In contrast, findings in this research differ from the conclusions confirmed by many international historical studies that flood risk information can more or less decrease housing prices (Belanger and Bourdeau-Brien 2017; Békés et al. 2016; Daniel, Florax and Rietveld 2009; Gibson and Mullins 2020; Ortega and Taşpınar 2018). Such differences emphasise the unique characteristics of New Zealand's housing market.

5 Discussion

5.1 Potential Consequences of Ignorance

The alignment of this research's findings with other studies in New Zealand (Filippova et al. 2020; Cheung and You 2022) highlights a consistent tendency within the country's housing markets to have a weak reaction to flood risk information. This indicates public ignorance of flood risk despite active flood risk information disclosure by local councils in local housing markets, which may lead to several consequences.

A straightforward consequence is the overvaluation of housing prices. Due to the lack of price reduction resulting from the flood risk, buyers must bear costs exceeding the reasonable value range. Some buyers may have even higher interest and insurance premiums (Daniel, Florax and Rietveld 2009). Besides this, because of this overvaluation, the economic damage caused by flooding events could be underestimated. Ortega and Taspinar (2018) found that, due to the public's lack of an appropriate understanding of flood risk, the actual economic loss dramatically exceeded public expectations. In contrast, with an appropriate understanding of flood risk, market resilience can be increased, and housing prices may be stable after flooding events (Yeo 2003). Meanwhile, overvaluing housing prices may cause buyers to misestimate the potential risk and also attract more investment in flood risk areas (Bagsta, Stapleton and D'Agostino 2007). This will contribute to the continued growth of at-risk properties.

5.2 Plausible Reasons for Risk Ignorance

There are various reasons for ignoring flood risk information in housing markets. On the one hand, stakeholders may actively choose to ignore risk information. On the other hand, buyers may passively be deprived of the opportunity to account for risk information in housing prices (Troy and Romm 2004; Hino and Burke 2021).

For those actively choosing to ignore the flood risk information, some researchers have indicated that, compared to publishing flood risk information itself, how the public perceives and understands such information actually influences housing prices (Bakkensen and Barrage 2021; Gibson and Mullins 2020; McCoy and Zhao 2018; Nguyen et al. 2019). This means that if flood risk information can be confirmed by actual flood events, such information is more likely to be capitalised in housing prices (Votsis and Perrels 2018). According to Nguyen et al. (2019), this aligns with the availability heuristic concept, where individuals tend to assess risk based on recent experiences or easily accessible examples. In contrast, if flood risk information is not supported by actual flood events, the local market may overlook its influence (Votsis and Perrels 2015). In Hamilton, flooding is not a common event, as suggested by the Hamilton City Council (2024), and at least in recent years, this city has not experienced severe flooding events. This may result in a phenomenon known as optimism bias in the local housing market, where buyers assume that floods are unlikely to damage the properties they purchase (Bakkensen and Barrage 2021; Nguyen et al. 2019; Gibson and Mullins 2020). Consequently, the market-perceived flood risk may differ from the information published by the Hamilton Council and result in an insignificant market response.

Meanwhile, the shortage of unified standards applicable nationwide may be another reason buyers ignore flood risk information. Researchers suggest this includes several aspects, such as the absence of exact minimum requirements for the level of risk information that must be disclosed and the lack of standardised measures for responding to such risks. Firstly, a lack of standardisation means accepting different regulations or practices in flood risk disclosure across various regions (Hino and Burke 2021; FEMA 2022). This may lead to varying responses to the same level of flood risk. Local housing markets may experience significant price reductions in some areas due to strict regulations, while buyers might overlook or underestimate the associated risks in other regions. Secondly, if local governments fail to clarify the legal authority of specific risk information and the necessary practices, its practical effectiveness may be undermined or overlooked (Hino and Burke 2021; FEMA 2022). This is because it may leave stakeholders uncertain (Beltrán, Maddison and Elliott 2018) about which risk information is most critical and what actions are necessary to mitigate it. In New Zealand, both of these situations have existed. For example, the central government has required local authorities to shoulder the main responsibility of publishing flood risk information to the public, as introduced in the study area section. However, there is still no national standard for published flood risk information. Criteria such as the legal authority of different risk levels, the format in which information is presented, and the platforms used for dissemination often vary significantly between urban councils. One noticeable example is that in Dunedin, a strict regulation for setting a Minimum Floor Level area (MFL) in floodplains significantly reduces housing prices (Nguyen et al. 2019; Nguyen et al. 2022). Other studies in urban areas that do not have solid regulations found the effects of flood risk information on the housing market are weak (Cheung and Yiu 2022; Filippova et al. 2020).

More specifically, flood risk information may confuse the public even in one city. Take the Hamilton City Council as an example. Currently, three maps, including Flood Hazards/extent, Overland Flow Path, and Flood Depression Areas, are shown on the Floodviewer (Hamilton City Council's online flood map). According to the information provided by the Hamilton City Council (Email communication with author, October 11, 2024), only the flood hazard information holds relative legal authority, but it does not account for areas with ponding water less than 10mm, and the flood extent data also lacks legal enforceability. Furthermore, besides including simple descriptions of these three maps on Floodviewer, the extent to which buyers should be concerned is not addressed. For instance, the map does not specify which information has legal implications or how a property might be affected during a flood event (Hamilton City Council 2024).

For those who are passively deprived of the right or ability to take risk information into account when determining house prices, ineffective communication between local governments and the public could be a contributing factor (Duncan and Boshoff 2023; Environment Agency, 2009). In Hamilton and other urban areas in New Zealand, although the online map is already more accessible than historical paperwork, buyers cannot immediately access the latest updated risk information unless they actively seek it out. Meanwhile, the LIM report indeed provides relative risk information, but this report needs to be purchased at a cost and will take about ten days to prepare (Local Government Official Information and Meetings Act 1987, 1988). This indicates that flood risk information will not be automatically conveyed to the public unless buyers actively seek the relevant information themselves.

In addition to the aforementioned explanation, external factors may also force buyers to not account for relevant flood risk information. These include rising housing prices and good amenities. Researchers suggest that if housing prices grow fast, it can overshadow concerns about flood risk information (Bakkensen and Barrage 2021; Votsis and Perrels 2015). Belanger and Bourdeau-Brien (2017) indicate that continuously rising prices can undermine buyers' negotiating power, making flood risk less likely to serve as a justification for price discounts. During the chosen study period of this research, New Zealand’s average housing prices nearly doubled within a very short period. Meanwhile, having a good view can mitigate the perceived impact of flood risk information (Atreya and Czajkowski 2014; Filippova et al. 2020). This is further supported by the findings of this research, as a scenic view consistently positively influences housing prices across all periods, thereby diminishing buyers’ negotiating power.

5.3 Implications for Planning

The issues discussed above undoubtedly pose considerable challenges to local councils. To address these challenges, transparent and proactive actions from councils at all levels are essential. A key aspect of this is establishing a unified standard with legal authority. Firstly, the central government must clarify which flood risk levels must be disclosed to the public. This would significantly reduce buyers' misunderstandings of flood risks (Cupal 2015; Dei-Tutu 2002; Filippova et al. 2020). The reason is that such criteria can dictate that when a flood risk reaches a specific level, the situation has become critical and requires necessary actions, and properties may face significant losses once a flood event occurs (Hallegatte et al. 2013). Secondly, in addition to establishing a unified standard for flood risk disclosure, there must also be standardized response measures for different flood risk levels. Examples in both the United States and New Zealand have shown that having a clear requirement for a necessary response to a certain level of flood risk can effectively influence housing prices (Nguyen et al. 2019; Nguyen et al. 2022; Hino and Burke 2021). These regulatory requirements may increase costs for both buyers and developers, thereby adjusting housing prices, even if flood risk information does not receive sufficient attention.

In addition, effective communication requires several necessary components. One key aspect is that a property's flood risk status must be noted before each transaction. This can ensure buyers understand the situation clearly, even if they do not check related information frequently. As mentioned above, setting necessary responses to a certain level of flood risk information can help achieve this goal. However, a mandatory report is also required. The LIM report does not have to be provided under the existing legal framework and must be purchased at a relatively high cost. This may prevent buyers from obtaining flood risk information prior to the transaction (Cheung 2022). Therefore, a risk assessment could be an independent document distinct from the LIM report, focusing solely on relevant risk information.

Furthermore, community-based sharing methods could be helpful and may even be necessary in some cases (Duncan and Boshoff 2023; Auliagisni, Wilkinson and Elkharboutly 2022). These methods can compensate for the shortage of traditional top-down communication. For example, frequent community meetings help refresh people and regularly remind them of flood risk information. Meanwhile, community grassroots workers can organise and interpret professional knowledge to the locals in a way that is more easily understood and accepted within the community.

5.4 Future Research

This research has been demonstrated to be robust and valid through rigorous regression analyses, empirical tests, and comprehensive discussions. Nonetheless, several aspects still merit further in-depth research. Due to the time restriction of the project, this research was able to obtain comprehensive flood risk information and detailed disclosure timelines from the Hamilton City Council only. This results in the research exclusively selecting Hamilton as the research area. In future studies, if there is sufficient time, it could be better to communicate with more local councils in more urban areas to obtain sufficient details about the disclosed flood risk maps. Specifically, research areas with contrasting characteristics could be selected to facilitate meaningful comparisons. Examples include comparisons between coastal and inland cities, urban areas experiencing rapid economic development versus those with slower growth, and councils with strict regulations versus those with more lenient policies.

Furthermore, the original purchased dataset contains transaction data until 2022, which restricts the sample size when researching the disclosure of the 2020 online map. Therefore, a comprehensive transaction dataset covering a longer period would provide more complete and reliable results in future studies. Specifically, aligning the time frames for each flood risk information disclosure would enhance the credibility of the analysis.

6 Conclusion

New Zealand has entered an era in which flood risk information is becoming more accessible to the public and more accurate. Increasing numbers of local councils have shouldered their responsibility, granted by the central government, to provide as much detail as possible. Meanwhile, the platform for publishing such information has changed from traditional to online maps. Until now, most regional and unitary authorities have launched online flood maps in some form (Walsh, Paulik and Robertson 2019). More information on different risk levels was provided in well-developed regions (such as Auckland and Wellington, for example). Still, councils like Invercargill do not publish much detailed information, due to the lack of resources and technological requirements. In Hamilton City, this trend is reflected in the fact that the local council successively disclosed 100-year floodplain maps on two occasions within ten years. This first flood risk map was published in the 2012 District Plan, and the second includes a series of updates of online flood maps in Floodviewer from 2020 to 2024. These results clarify the flood risk status of most urban areas in this city, and the public can check whether the property is in a disclosed flood risk area.

However, even though such risk information is much easier to access than before, it is surprising that the rate of transactions in floodplains has not changed over time. This shows that buyers in New Zealand are careless about the announced flood risk information. Most results in New Zealand research, including this study, have confirmed this lack of awareness and carelessness. For example, this study utilises the DID and Repeat-Sale models to examine the effects of disclosing such risk information on the local housing market. The findings highlight the nuanced influence of such disclosures in 2012 and 2020.

The DID model results indicate that only the period spanning 8 years before and after the 2012 disclosure shows a statistically significant adverse effect at the 0.05 level, while other periods show no apparent effect. In contrast, the Repeat-Sale model indicates that property values increased following the disclosures.

These two methods effectively complement each other's shortcomings. By focusing on the same properties with different flood risk statuses over time, the Repeat-Sale model successively overcomes the heterogeneous issue of the DID model. Meanwhile, the shortage of limited observations in the Repeat-Sale model is also effectively addressed by the DID model. Therefore, the combination of these two methods can provide more robust results in estimating the effect of disclosing flood risk information on housing prices. The robustness tests, which included the application of different data trimming methods, confirmed the results' reliability.

Besides proving the neglect of flood risk information among home buyers, this study also confirms that simply changing the platform for disclosing flood risk information may not effectively change the expectation of flood risk in the local housing market in New Zealand. This may contradict the prevailing global findings, which suggest that disclosing flood risk information tends to significantly reduce housing prices. This difference may, firstly, stem from the mismatch between officially published flood risk information and public perception. Secondly, the lack of national standards and inefficient communication mechanisms may also have contributed. This means that a more direct communication mechanism with a unified national standard is urgently needed in New Zealand to correct the public's inherent perceptions of flood risk.

Building on these findings, this study makes a valuable contribution by filling the knowledge gap regarding the impact of changing flood risk disclosure methods on housing markets. First, the combination of the DID and Repeat-Sale model was used in the field of study in New Zealand. It provides a more solid and robust methodology for researching topics related to the effects of disclosing risk. Second, the results of this research suggest that flood risk information alone may not significantly influence housing prices. More importantly, it reveals a critical insight: merely shifting the disclosure platform—from traditional paperwork formats to online maps—does not fundamentally reshape public perceptions of flood risk. This highlights the need for a more comprehensive approach to risk communication and a national standard. Future research should explore strategies for effectively bridging the gap between disclosed information and public understanding, focusing on conveying flood risk in a manner that fosters informed decision-making. Such efforts could be pivotal in supporting urban planning and improving resilience to New Zealand's natural hazards.

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Appendix A: Whau River Catchment

1. Whau River Catchment

After consulting with the Auckland City Council, this study includes the Whau River Catchment as part of the research area to facilitate a comparison between an inland city and a coastal city, enhancing the robustness of the model. The Whau River Catchment was selected due to its sufficient number of single dwellings, comparable to the housing situation in Hamilton City. However, given the limited sample size available for the Repeat-Sale model, the housing market in this area will only be used for the DID analysis.

On 14 November 2020, Auckland City Council uploaded the floodplains map of this catchment online, which are shown on Figure 7. Auckland is a coastal and the largest city in New Zealand. Compared to Hamilton, it has a more spectacular coastal view and a more well-developed local economy and infrastructure. Meanwhile, the frequency of flooding events in Auckland is also higher than in Hamilton. In January 2023, Auckland was hit by a destructive hurricane event. The interactive map shows that properties in Whau River Catchment were damaged severely during this event (Knox and Gabel 2023), which undoubtedly shows that suburbs in this area are at a relatively high level of flood risk. Using this coastal area as a sub-research area can help this study discuss whether there is a difference in the discount effect of housing prices due to the coastal characteristics. Unfortunately, since the original transaction dataset utilized in this study only contains records until the end of 2022, only two years before and after the flood risk map disclosure can be used in Whau River Catchment. Therefore, this study cannot discuss the influence of the 2023 flooding event.

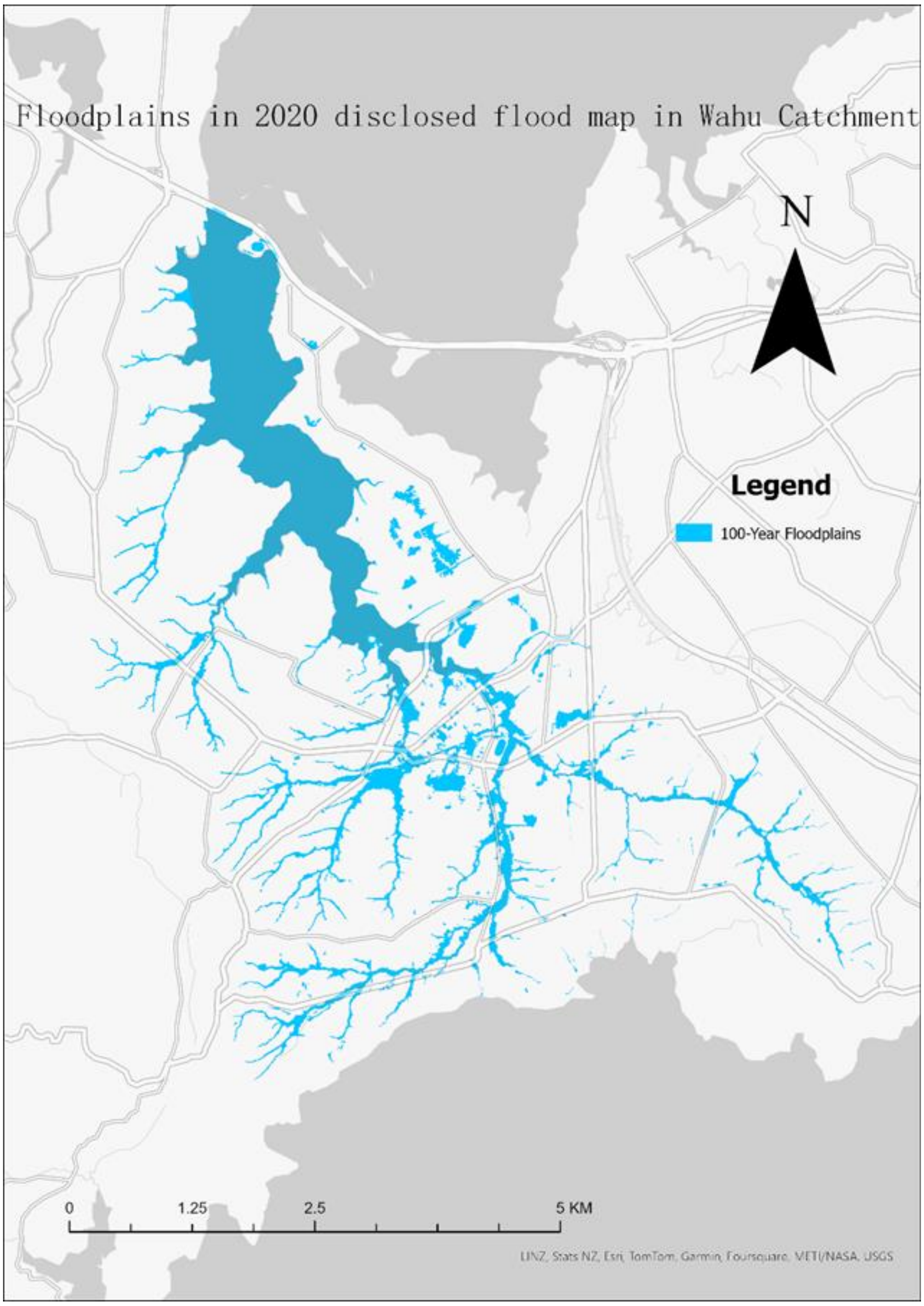

Figure 7: Whau River Catchment Floodplains Uploaded on November 14th, 2020

2. Dataset for Whau River Catchment

As mentioned, Whau River Catchment in Auckland is accepted as a sub-research area for the robustness test. Therefore, the transaction records in this area are collected, cleaned, and selected using the same process as Hamilton City.

In this sub-research area, data for the housing market was also purchased from CoreLogic, and other geospatial datasets were obtained from similar sources. Auckland City Council provided the floodplains map and confirmed it was uploaded on November 14th, 2020. As a result, this research selects the transaction records between 2018 and 2022 in this area to conduct the DID analysis. However, there are only four transactions involving two properties located within the published floodplains in this area, both of which were sold before and after the disclosure. This limited sample size renders the Repeat-Sale model's results unreliable. Consequently, only the DID analysis results for the Whau River Catchment will be reported. Table 11 shows the summary statistics. used for the DID Model after using the 1.5*IQR trimming method.

Compared to Hamilton City, the average building area in Whau River Catchment shows no significant difference. However, the average land area in this area is dramatically smaller during the same period. Meanwhile, the average selling price is considerably higher. The combination of this data may indicate that properties in the western part of Auckland's central area are significantly more expensive in terms of average total house price and price per square meter. The proportion of properties with a view in the Whau River Catchment is approximately twice that of Hamilton. This may be attributed to its coastal location, where many properties enjoy scenic water views.

Table 11: Statistics for Whau River Catchment (1.5*IQR)

	3-year Before and after 2012
FP (Proportion)	0.021
PD (Proportion)	0.411
Sale_Price(mean)	892811.447
Building_Area(mean)	128.910
Land_Area(mean)	261.643
View (Proportion)	0.246
Modernisation (Proportion)	0.094
Built_Age	42.512
Bathrooms(mean)	1.470
SA2 Count	35
Observation	3740

3. Regression results of Whau River Catchment

Whau River Catchment is a coastal area in the western part of the Auckland central area. It has an entirely different natural and socioeconomic environment from Hamilton City. However, the core interaction variable, FP x PD, still remains insignificant. On the one hand, this alignment suggests that the robustness of the DID model is well-supported in researching the effects of flood risk information on the housing market. On the other hand, it also indicates that the neglect of flood risk information may be a broader, systemic situation in the New Zealand housing market instead of a localised issue.

Table 12: DID results for Wahu Catchment, Auckland (1.5*IQR)

	Whau River Catchmant
FP x PD	0.040 (0.048) n.s.
FP	-0.104 (0.020) *
PD	0.057 (0.014) *
Building_Area	0.003 (0.000) ***
Land_Area	0.000 (0.000) n.s.
View	0.007 (0.004) ***
Modernisation	0.033 (0.008) ***
Bathrooms	0.060 (0.005) ***
Built_Age	0.003 (0.000) **
Quarter	Controlled
SA2_Year	Controlled
Observation	3693
A-R2	0.507

However, as previously mentioned, the Repeat-Sale analysis in the Whau River Catchment cannot be conducted due to the minimal sample size of transaction records. This once again confirms that, although this model can effectively address the biased estimation result from the heterogeneity issue among different properties, it dramatically reduces the potential sample size. This will place higher demands on the scale of the original dataset.

Appendix B: Statistic Summary and Regression Results for Hamilton Using 3SD and 1*IQR

Table 13: DID Statistics for Key Variables Across Time Periods (3SD)

	3-year Before and after 2012	5-year Before and after 2012	8-year Before and after 2012	2020 Online Disclosure
FP (Proportion)	0.047	0.049	0.051	0.059
PD (Proportion)	0.588	0.583	0.504	0.317
Sale_Price (mean)	365602	400927.1	404806.5	680153.3
Building_Area (mean)	130.1	130.2	130.1	142.8
Land_Area (mean)	742.1	657.5	1242.5	6679.8
View (Proportion)	0.145	0.144	0.142	0.143
Modernisation (Proportion)	0.105	0.111	0.115	0.129
Built_Age (mean)	34.47	34.47	33.44	40.44
Bathrooms (mean)	1.392	1.393	1.4	1.441
SA2 Count	61	62	62	60
Observation	15924	27129	46860	7152

Table 14： DID Statistics for Key Variables Across Time Periods (1*IQR)

	3-year Before and after 2012	5-year Before and after 2012	8-year Before and after 2012	2020 Online Disclosure
FP (Proportion)	0.048	0.051	0.054	0.062
PD (Proportion)	0.585	0.572	0.477	0.288
Sale_Price (mean)	355063.5	380944.5	374617.7	637798
Building_Area (mean)	128.289	126.687	125.661	135.897
Land_Area (mean)	732.522	643.659	955.807	7134.637
View (Proportion)	0.136	0.134	0.13	0.128
Modernisation (Proportion)	0.102	0.108	0.111	0.123
Built_Age (mean)	34.534	34.785	33.718	40.737
Bathrooms (mean)	1.374	1.364	1.361	1.397
SA2 Count	61	62	62	60
Observation	15611	25990	43950	6629

Figure 8: DID Results for FP x PD Interaction (3SD)

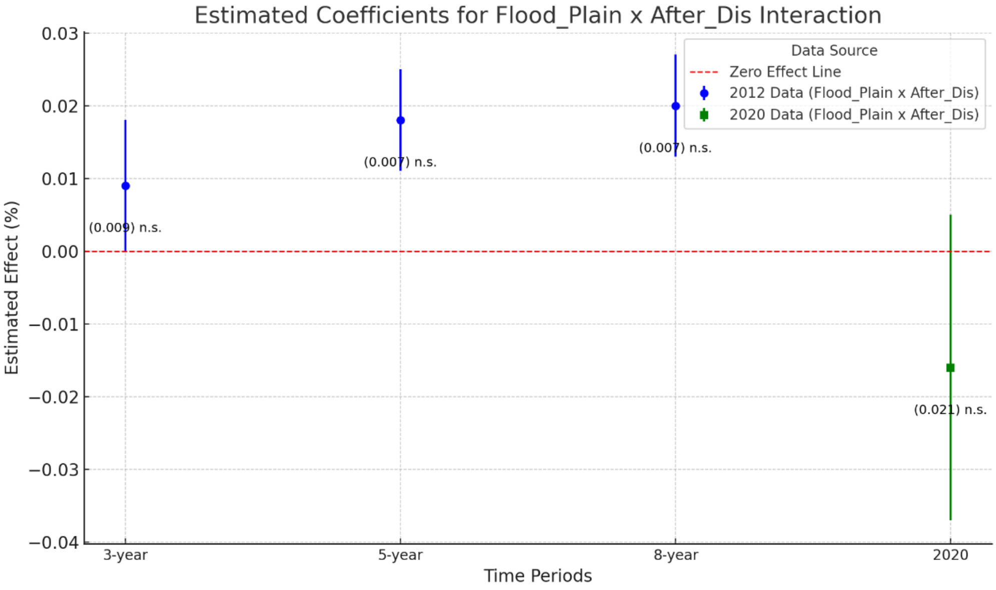

Figure 9: DID Results for FP x PD Interaction (1*IQR)

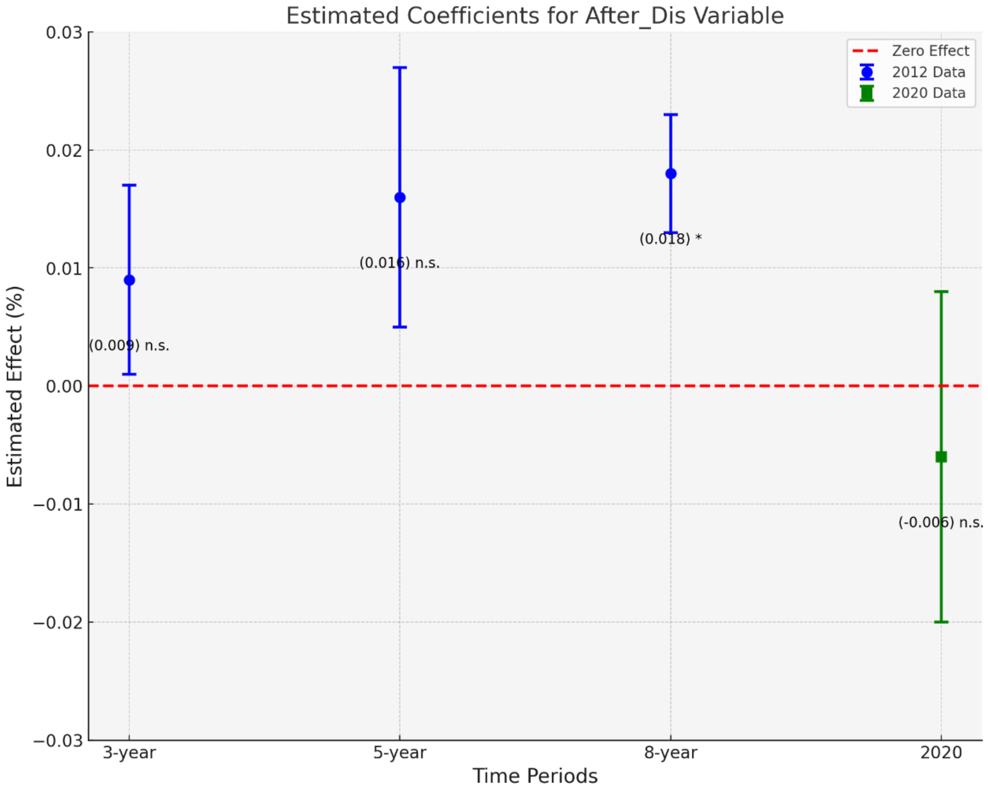

Table 15: Repeat Sale Statistics for Key Variables Across Time Periods (3SD)

	3-year Before and after 2012	5-year Before and after 2012	8-year Before and after 2012	2020 Online Disclosure
PD (Proportion)	0.497	0.511	0.478	0.5
Sale_Price (Mean)	276354.2	305951.3	305050.3	697001.9
Built_Age (Mean)	39.1	38.78	36.93	49.69
Modernisation (Proportion)	0.088	0.091	0.073	0.154
SA2 Count	18	22	24	9
Observation	147	450	1178	26
QPID Count	71	191	412	13
Observation/QPID	2.07	2.36	2.86	2

Table 16: Repeat Sale Statistics for Key Variables Across Time Periods (1*IQR)

	3-year Before and after 2012	5-year Before and after 2012	8-year Before and after 2012	2020 Online Disclosure
PD (Proportion)	0.497	0.511	0.476	0.5
Sale_Price (Mean)	276354.2	304649.7	301294.5	597820.5
Built_Age (Mean)	39.102	38.902	37.135	49.045
Modernisation (Proportion)	0.088	0.092	0.074	0.091
SA2 Count	18	22	23	7
Observation	147	448	1164	22
QPID Count	71	190	407	11
Observation/QPID	2.07	2.36	2.86	2

Figure 10: Repeat Sale Results for PD (3SD)

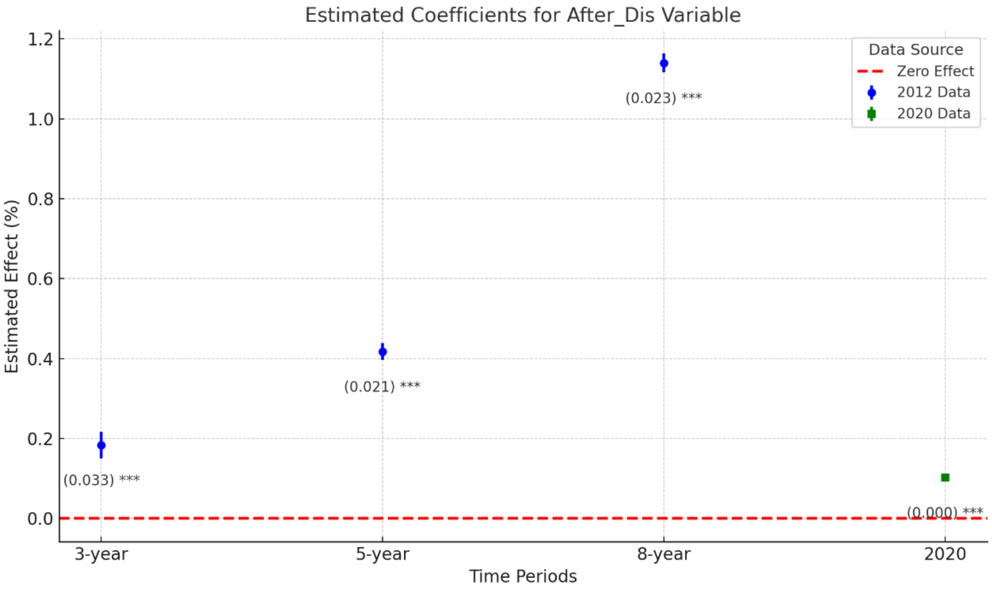

Figure 11: Repeat Sale Results for PD (1*IQR)