Liquefaction and the Law: Understanding Challenges and Failure to Strengthen Hazard Management Regulations

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Liquefaction is a significant reduction in the strength of saturated granular or sandy soils by shaking or vibration, often resulting in the failure of building foundations and deposition of groundwater or liquefied sediment above the ground surface. The damage liquefaction caused in the Christchurch earthquakes of 2011 highlighted the importance of effective hazard management. However, years after the fact, liquefaction remains absent from much of New Zealand law. The following article analyses why this gap remains by outlining the specific challenges raised by liquefaction as a hazard. It is concluded that assumptions made by planning theory such as the importance of preparedness, mitigation and education pose fundamental problems to implement in practice, compelling lawmakers to make inevitable compromises between present and future need. It is therefore proposed that a solution should consist of a change in form of local plans to increase transparency and clarity, largely by following the requirements of outlining objectives, policies and methods under the Resource Management Act 1991.

1. INTRODUCTION

The earthquakes which hit Christchurch on 22 February 2011 (the Christchurch earthquakes) were perhaps the worst instance of liquefaction in recent history,

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causing millions of dollars' worth of damage to infrastructure and private property. Awareness of the hazard thus heightened drastically across the country. However, despite an increase in public and expert cognisance of liquefaction hazards, New Zealand law remains almost mute to the hazard years after the Christchurch earthquakes. This article will highlight the challenges faced by hazard planners to better understand why the law fails to implement effective mitigation of liquefaction.

First, the challenges of liquefaction will be examined by outlining the uncertainty of its science. Opinions of earthquake engineers and modern hazard planning theory will be applied to discover the ideal of liquefaction mitigation, resting largely in planning foresight and engineering technology. The reality of liquefaction planning will then be explored by examining the law, and how effectively it manifests these ideals. What will be found is a lack of explicit mention of liquefaction, and a vague framework in place for hazard mitigation more generally. The disconnect between theory's ideal and the legal reality will then be critically explored, using liquefaction as a case study. Several reasons may exist for this gap in the law, including the compounding difficulties raised by liquefaction specifically, and the prioritisation of present need over future risk. However, what will become apparent is a problematic vagueness of the law in relation to hazard planning, parroting key words like resilience and mitigation but doing nothing to implement them. This is not just an issue for liquefaction, but for all hazards.

Ultimately, this article calls for clarified law to address liquefaction before a repeat of the Christchurch earthquakes occurs. It also concludes that hazard planning theory, as the model much of the law relies on, must be more critically examined. There appears to be a trend towards critical environmental theory being written with an optimistic tone, making it appear more empowering than it may be in practice. The effect is the reduction of engagement with its language and themes, turning them into "buzz words" and reducing their real-world effectiveness. Implementing hazard management is potentially more complicated and difficult in practice than in theory, and it is important to acknowledge this divide to tackle dangerous gaps in the current legal framework.

2. PLANNING AGAINST LIQUEFACTION

This article will examine the challenges of planning against the risk of liquefaction across New Zealand. It will do so by examining the unique problems posed by liquefaction as a hazard, the risk it poses to New Zealand, and what modern engineering and planning theory calls for as a solution.

2.1 Nature and Impacts of Liquefaction

As stated above, liquefaction largely occurs during seismic events, causing liquefying of soil and ejection of groundwater from below. Only waterlogged, fine sandy soils on flat land will liquefy, as the hazard is caused by the particles within the soil attempting to densify, but being prevented by the water between them. They begin to float in the water and act like a liquid, therefore losing strength and spreading laterally.[1] Structures built on this surface may distort and crack, damaging their foundations or structural integrity, as occurred to numerous buildings in Christchurch.[2] Inundation of groundwater may damage underground infrastructure.[3] The upwelling effect may also eject material to the surface, leaving behind a dark silt once the water is cleared. These three impacts combined are predicted to have contributed towards half of the economic loss sustained by Christchurch in 2011.[4]

These effects are extremely costly to property and quality of life in the aftermath of an earthquake. Falling structures or land subsidence are the biggest threats to life in an earthquake and while it is challenging to calculate liquefaction's contributions towards these events, it is unlikely to be the primary cause.[5] However, this should not downplay liquefaction's potentially devastating toll. Damage to infrastructure prevents access to important utilities like electricity and clean water during recovery efforts. Foundational subsidence can render homes uninhabitable and inundation may cause property to become unsanitary. Therefore, many unlucky survivors of an earthquake may be forced to choose between being homeless or living in untenable conditions immediately after an earthquake, when they are most vulnerable.

Liquefaction also changes the properties of the land. It causes lateral spreading near waterways, creating large cracks in banks. Ground is also often lowered permanently towards the water table, creating ponds and increasing susceptibility to flooding. This may also cause the area to be more susceptible to liquefaction in future, though other areas may become less susceptible if liquefaction sufficiently densifies the soil.[6]

1 *Christchurch Earthquake — An Overview* (Institution of Professional Engineers of New Zealand, March 2011) at 5.

2 J Bray and others "Liquefaction effects in the Central Business District of Christchurch" in RP Orense, I Towhata and N Chouw (eds) *Soil Liquefaction during Recent Large-Scale Earthquakes* (Taylor & Francis Group, London, 2014) 109 at 115.

3 Institution of Professional Engineers of New Zealand, above n 1, at 2.

4 *Module 3: Identification, assessment and mitigation of liquefaction hazards* (Ministry of Business, Innovation and Employment and New Zealand Geotechnical Society, May 2016) at 3.

5 Bray and others, above n 2, at 117.

6 Institution of Professional Engineers of New Zealand, above n 1, at 6.

2.2 Risk of Liquefaction

Efforts have been made in a few areas of New Zealand to calculate liquefaction risk. Three of New Zealand's fastest-growing areas, Auckland, Christchurch and Hamilton, are located on flat land near water,[7] which presents the highest risk of the hazard.[8] Furthermore, various areas in Canterbury may have increased susceptibility to liquefaction due to experiencing it previously.

The estimation of risk is relatively reliable at a regional scale but more difficult at localised scales. While liquefaction created dramatic results in the red zone of Christchurch, many areas with a similar soil profile were not affected.[9] Furthermore, different earthquakes and aftershocks in Christchurch created different effects. Liquefaction's damaging impacts are caused by a variety of different factors including soil type and density, crust thickness and seismic intensity. While there are many different parameters and models for calculating local vulnerability, even the best identified are subject to uncertainty.[10] Furthermore, the detailed surveys necessary to adequately estimate the risk would be a very costly exercise. Therefore, while it is understood that much of urban New Zealand is at risk of liquefaction, which locales and extent of risk are less well understood.

2.3 Mitigating Liquefaction

Mitigating liquefaction is often costly, slow, requiring foresight, or all three. Therefore, both social scientists and engineers call for regulation as an effective tool to coordinate communities and implement these techniques to build resilience against the threat.

2.3.1 Engineering methods

Engineering methods are the main techniques used to counter the threat of liquefaction, and have been used in New Zealand. They aim to either prevent liquefaction by improving ground conditions, or minimising damage through

7 JE Kim "From Crisis to Opportunity: Recovering Community on Uninhabitable Land" (MA Thesis, University of Auckland, 2013) at 63.

8 T Kiyota and others "Mitigation of liquefaction-induced damage to residential houses by shallow ground improvement" in RP Orense, I Towhata and N Chouw (eds) *Soil Liquefaction during Recent Large-Scale Earthquakes* (Taylor & Francis Group, London, 2014) 157 at 158.

9 Tonkin & Taylor *Liquefaction Vulnerability Study* (Earthquake Commission, February 2013), Executive Statement.

10 At 45.

structural strengthening.[11] A common observed measure is compacting the ground to ensure it remains firm, often combined with structural strengthening and inserting drainage, which has achieved successful outcomes in previous earthquakes.[12] Other methods include imbedding structural walls into the earth for stability, or lowering the water table, which could also protect underground infrastructure.[13] While these methods are usually executed before development occurs, they can be implemented to existing structures but with difficulty and often at higher cost.[14] Furthermore, very little literature pertaining to the environmental outcomes of these methods exists, which makes calculating their full costs problematic.

To ensure optimum implementation of these methods engineers stress the importance of codes and minimum standards, which are promulgated by legislation.[15] Worldwide, there is growing implementation of legal regulation to strengthen building standards in combating earthquake hazards, as mandatory building codes and prudent urban planning has been proven to be correlated with increased building strength against earthquake.[16]

2.3.2 Hazard planning and resilience theories

Planning theory aims, among other things, to provide new approaches for planners and communities to better address the impacts of natural hazards. It recognises that hazards are created not just from the occurrence of a natural event, but from a natural event impacting upon human settlement. Therefore, while previous planning methods focused on controlling the hazard itself,[17] modern theories now revolve around the idea of resilience, or building a

11 K Harada and others "Verification of effectiveness of liquefaction countermeasures during past large scale earthquakes in Japan" in RP Orense, I Towhata and N Chouw (eds) *Soil Liquefaction during Recent Large-Scale Earthquakes* (Taylor & Francis Group, London, 2014) 181 at 182.

12 At 182.

13 S Yasuda "New liquefaction countermeasures for wooden houses" in RP Orense, I Towhata and N Chouw (eds) *Soil Liquefaction during Recent Large-Scale Earthquakes* (Taylor & Francis Group, London, 2014) 167 at 175.

14 Harada and others, above n 11, at 190.

15 CS Oliveira, A Roca and X Goula "Assessing and managing earthquake risk: an introduction" in CS Oliveira, A Roca and X Goula (eds) *Assessing and Managing Earthquake Risk* (Springer, Dordrecht, 2006) 1 at 6.

16 At 10.

17 BC Glavovic, WSA Saunders and JS Becker "Land-use planning for natural hazards in New Zealand: the setting, barriers, 'burning issues' and priority actions" (2010) 54 Natural Hazards 679 at 682.

community's adaptive capacity to withstand or bounce back from disaster through anticipation, mitigation and measured response.[18]

Resilience theory provides an interdisciplinary response to hazard management and aims to empower vulnerable communities. It heralds a move away from the "protective work" of engineering methods as this encourages less strategic planning which can result in greater damage in the long term.[19] Instead, it encourages a cycle of mitigation, preparedness, response and recovery in the face of hazards, capitalising on every community resource.[20] Resilient communities are supposedly educated about risk and have high social coordination. Therefore, one of the most important mitigation tools of a planning theorist is national and local law, which comprise the largest operative plans of the community.

Planning theory is largely focused on outlining methods instead of specific plans, providing approaches towards resilience that officials may adopt within the specific circumstances and challenges of their area.[21] This preference of general form over specific instruction occurs due to the theory's value of adaptation. Few planning theories have therefore discussed approaches towards building resilience in anticipation of liquefaction specifically, leaving it to officials to educate themselves on the best approaches to address it individually.

2.4 Conclusion

The uncertainties associated with the science of liquefaction and its mitigation show how challenging a hazard it is to address. Liquefaction is difficult to predict and able to affect seemingly similar areas differently, yet its impacts can be widespread and significant. Mitigating the associated risk requires good planning and foresight to be effective, yet countermeasures can be costly. However, experts in the field all appear to agree on the importance of strong regulation to best mitigate liquefaction exactly because of this uncertainty. Therefore, the best defence against liquefaction in New Zealand's largest centres can be argued to be its legal framework.

18 J Hicks Masterson and others *Planning for Community Resilience* (Island Press, Washington DC, 2014) at 38 and 39.

19 Glavovic and others, above n 17, at 682 and 693.

20 Hicks Masterson and others, above n 18, at 42.

21 At 22.

3. LIQUEFACTION IN THE LAW

This part of the article will explore the way New Zealand has addressed liquefaction in the law. Both national and local law will be explored as both are intended to work together to best coordinate effective hazard planning to meet the needs of each locale.

3.1 Building Act 2004

The Building Act 2004 contains provisions that govern the approval of construction and its compliance with the New Zealand Building Code.[22] It would therefore be the primary tool in implementing the liquefaction counter-measures engineers have suggested. The Act allows authorities to reject building consents based on the property's risk of natural hazards.[23] However, the Act appears to exclude liquefaction from the definition of natural hazard. Section 71(3) defines "natural hazard" with a list of hazards instead of a general definition:

> (a) erosion (including coastal erosion, bank erosion, and sheet erosion):
> (b) falling debris (including soil, rock, snow, and ice):
> (c) subsidence:
> (d) inundation (including flooding, overland flow, storm surge, tidal effects, and ponding):
> (e) slippage.

The list is exhaustible as it focuses on hazard characteristics, not impacts. It is therefore difficult to interpret liquefaction within this definition. While liquefaction can cause inundation and erosion, its greatest impact — loss of support to building foundations — is not included in s 71(3)(d). This suggests lawmakers either lacked intent to accommodate liquefaction within the scope of the provision or were simply not aware of its importance.

The Building Code of New Zealand provides nominally more guidelines for natural hazard planning by stating "Account shall be taken of all physical conditions likely to affect the stability of *buildings, building elements* and *sitework*, including … earthquake".[24] While liquefaction is usually caused by earthquakes, its physical conditions are unique compared to other earthquake impacts. Therefore, the term "earthquake" only obscures liquefaction from officials. Furthermore, the wording of the Code fails to put any hard obligations

22 Building Act 2004, s 3.
23 Section 71(1)(a).
24 Building Regulations 1992, sch 1 at B.1.3.3(f) (emphasis in original).

on officials, stating that they should only take "account" of hazards in relation to building stability.

In accordance with s 175 of the Building Act, the Chief Executive of the Ministry of Business, Innovation and Employment has published management guidelines for liquefaction. However, they are not mandatory to follow and officials have discretion to make decisions excluding liquefaction under s 71(3)(d). Notably, the guide stresses the importance of relying on professional understanding when considering liquefaction as a hazard.[25] Therefore, the guide appears to be a step towards the government's new geotechnical education programme.[26] While this document may be important in giving experts a guide and increasing their awareness of liquefaction risks and impacts, it ultimately places responsibility on the individuals to act against liquefaction.

Liquefaction is present in the Building Act, but only in the form of non-binding legal instruments. Therefore, the Building Act fails to impose the minimum standards engineers have stated as necessary.

3.2 Resource Management Act 1991

As the leading environmental legislation in New Zealand, the Resource Management Act 1991 obliges local authorities to create hazard management plans and provides a guideline to follow. In this way, it is important to implement mitigation techniques under planning theory.

Both regional and district councils have the function of avoiding or mitigating natural hazards in their control of the use of land, under ss 30(1)(c)(iv) and 31(1)(b)(i) respectively. Regional plans are to be written and implemented according to s 65(1), and district plans similarly under s 73(1). These must be in line with regional policy statements, which may also consider hazard management due to falling in accordance with s 30(1)(c)(iv). This management is to be conducted by implementing and reviewing objectives, policies and methods.[27] Therefore, the Resource Management Act establishes a clear and transparent approach councils must follow to satisfy their obligations of hazard management under the Act. Compelling both councils to consider hazards also creates overlapping levels of preparation: one at a more localised district level, and one at a larger regional level.

Therefore, the Resource Management Act requires natural hazards to be planned against, but allows for spatial flexibility in targets and approach. Councils are free to invest more resources towards bigger risks to their region

25 Ministry of Business, Innovation and Employment, above n 4, at 3.

26 Ministry of Business, Innovation and Employment "Geotechnical education" Building Performance <www.building.govt.nz>.

27 Resource Management Act 1991, ss 30(1)(a) and 31(1)(a).

and ignore hazards that are lower risk. Therefore, to best understand how liquefaction specifically is discussed in the law, various plans must be studied.

3.3 Local Plans

While the flexibility granted to councils in addressing hazards allows for greater adaptability, it also creates the risk of inconsistency. Some councils have more robust plans than others in relation to earthquake hazards, which is not necessarily explained by the associated level of risk. The following exploration considers local plans of territories with a significant liquefaction risk and rapid development, making liquefaction readiness particularly important.

3.3.1 Proposed Auckland Unitary Plan

Auckland is New Zealand's fastest-growing city, containing a third of its population and the country's most expensive property. Therefore, a liquefaction event could be devastating. Its Proposed Unitary Plan, which is intended to be operative shortly, proposes a general approach to hazard management, not outlining any hazard-specific planning but an approach for avoiding all hazards. It does name hazards Auckland may be susceptible to, including earthquake, but not liquefaction specifically.[28]

The Plan has several different objectives, policies and methodologies for hazard management outlined across two different sections. While the provisions are broadly stated and potentially inclusive of liquefaction, the Plan acknowledges its focus includes coastal erosion, flooding and wildfire, but not liquefaction.[29] This is possibly reflective of Auckland's relatively low frequency of earthquake, though the Plan explicitly acknowledges risk is not only made up of frequency but vulnerability.[30] Therefore, while the Plan recites broad planning ideals, its provisions to implement methods and rules do not reflect them.

Furthermore, there is a risk that broadly stated provisions create the risk of inaction. Few provisions are targeted toward specific hazards, which provides less guidance to administrators. The Plan requires administrators to "manage", "mitigate", and "assess risk" generally without detailing how this will be done.[31]

28 Auckland Council *Proposed Auckland Unitary Plan* (Decisions version, 19 August 2016) at B10.6.
29 At E36.1.
30 At B10.6.
31 At B10.2.2.

3.3.2 Waikato Council plans

Close to Auckland, the Waikato is also developing rapidly. However, unlike its neighbour, large areas of the Waikato are located on infilled swampland and are at significant risk of liquefaction. Like the Auckland Unitary Plan, its Regional Policy Statement uses terminology direct from planning theory — calling for community resilience, risk reduction and effective response to natural hazards. It also provides general policies and methods to achieve these objectives.[32]

The operative Hamilton District Plan provides a more transparent approach, to a troubling degree. It admits non-existent knowledge of the hazards that the city is most vulnerable to, but still requires the implementation of methods which best target known hazards.[33] While this lack of knowledge is problematic, this plan notably does refer to specific sources to achieve its objective of mitigating hazards including council work programmes, the natural hazards register, and the Building Act.[34] The proposed Hamilton District Plan does name specific hazards, outlining "earthquakes" generally without including liquefaction.[35]

3.3.3 Canterbury Council plans

As a direct victim of liquefaction, Canterbury's plans provide in-depth coverage of liquefaction in the law. These plans contain the only discussion of liquefaction and its unique challenges as separate from earthquake hazards more generally, while also providing the most comprehensive methodology for addressing it.

Liquefaction features prominently in both the Canterbury Regional Policy Statement and the proposed Christchurch City Plan. Both contain objectives of avoiding damage to property by natural hazards as well as provisions related to liquefaction specifically, putting it at the forefront for those administering the plans.[36] But the most notable aspect of these plans is their level of detail. An effective feature of the Canterbury Regional Policy Statement is its "Principle Reasons and Explanation" excerpts following many of its policies, explaining their importance.[37] These statements are invaluable at clarifying the intentions

32 Waikato Regional Council *Waikato Regional Policy Statement* (May 2016) at 3.24.

33 Hamilton City Council *Hamilton District Plan* (July 2012) at 1.3.3.

34 At 3.2.1.

35 Hamilton City Council *Proposed District Plan* (2016) at 22.1.b.

36 Canterbury Regional Council *Canterbury Regional Policy Statement* (December 2013) at 129 and Christchurch City Council *The Proposed Christchurch Replacement District Plan* (August 2014) at 5.1.1.

37 *Canterbury Regional Policy Statement*, above n 36, at 133.

of the drafters, as well as providing basic information about hazard mechanics and planning that less educated officials may find beneficial.

The City Plan methodology is notably detailed, including laying out its resource consent schema in full. No activities within liquefaction risk zones are permitted without a resource consent.[38] This ensures that experts and officials will examine all proposed development. Furthermore, the red zone most affected by the earthquake has been zoned off from development as "recovery" land, in direct recognition of liquefaction's high risk in that area.[39] Of all the law examined as input to this article, the Canterbury plans most resemble a code of minimum standards in relation to liquefaction risk.

On the other hand, the plans' emphasis on avoidance may shift focus away from existing development. Despite zoning the entire centre of Christchurch as a liquefaction risk, strategies to potentially mitigate the susceptibility of old buildings are sorely lacking. This may be because the Council has deemed such mitigation infeasible, shifting their focus towards awareness instead, though this is not stated.

3.4 Conclusion

Liquefaction remains relatively absent in the law compared to other natural hazards. Unsurprisingly, it is most represented in the local laws of Canterbury which also contain the most robust liquefaction hazard management plans of any region examined, reflective of the region's acute awareness of the hazard. While the Auckland and Waikato plans use terminology frequently found in planning and resilience theories, they are untargeted and vague, reducing their regulatory power. It is apparent that there exists a fundamental disconnect between what is called for in theory and what is manifested in practice. Preparedness is ultimately what experts advocate for when discussing mitigation of natural hazards including liquefaction, yet most council plans remain too vague to ensure adequate management of the risk.

4. CRITIQUE AND PROPOSALS

Is the failure of New Zealand law to address liquefaction a problem in substance, or does it reflect the mounting difficulties in implementing modern hazard planning theory? This part of the article will answer this question by relating the problem to a fundamental tension in hazard planning policy: the

38 *Proposed Christchurch Replacement District Plan*, above n 36, at 5.9.1.

39 Christchurch City Council *The Proposed Christchurch Replacement District Plan* "Planning Map 26" (September 2016).

importance of effective hazard avoidance created by cautionary planning versus the need to provide for the needs of a developing community. Each need undermines the other. Fast-developing regions are more likely to build into hazardous areas out of necessity which forces planners to move from hazard avoidance to hazard mitigation and the old protective methods of planning. This dynamic essentially poses present needs against future risk — both important, but one more immediately necessary than the other.

This part does not seek to undermine the importance of meeting present development demand, nor the importance of prudent hazard planning. However, it does aim to highlight the importance of this tension in relation to occurrences of actual practice. Hazard planning theory is generally of a conservative yet optimistic flavour which simply is not realistic in many instances. The impact is the creation of flimsy regulation which at best echoes the ideals of planning theory without effectively implementing them. At worst, regulation fails to address a hazard completely, or relies on ineffective old methods to fill any gaps. Liquefaction is an important case study in this analysis because it presents some of the most difficult challenges in hazard planning: being relatively novel, uncertain, costly to address, a significant risk to existing urban areas which cannot enjoy the benefits of intelligent planning, and occurring within a larger hazard that poses potentially more dangerous risks like landslides and structural collapse that take precedence in planning efforts. This makes liquefaction almost impossible to realistically address by councils without severe compromise.

4.1 Critique of Resilience Theory as Applied to Liquefaction

This section aims to highlight the practical issues of resilience theory by applying it to the unique hazard of liquefaction, and will use this interface to explore the challenges lawmakers face. Resilience as a term has been increasingly used in academia across many different fields. Planning has borrowed definitions from other fields. In engineering, resilience relates to a community's ability to "bounce back"; while in ecology it more closely refers to a community's capacity to withstand an impact.[40] Due to this aspirational quality, finding any person against the general idea of resilience would be a difficult search. However, the term is now being so freely used as a part of planning discourse that critical engagement with the concept is appearing to falter, muddying its meaning. Because planners and lawmakers heavily rely on the concept in forming practical strategies against hazards, this is problematic.

40 S Davoudi "Resilience: A Bridging Concept or a Dead End?" (2012) 13(2) Planning Theory and Practice 299 at 300.

Without critical understanding in its implementation, reliance on resilience theory will only weaken law and policy, not strengthen it.

Fundamental to resilience theory are the assumptions it is built upon, adopted by both ecological and engineering paradigms. General preparedness, intelligent planning, mitigation, education and bouncing back are all considered important tools in building resilience for all communities, against all hazards. In general, they are important to implement, but also create other challenges when written into law or implemented in practice. Furthermore, different ideas of resilience may conflict. The goal of bouncing back, on one hand, encourages reversion to the status quo after liquefaction occurs at the risk of repeating the same event in future. On the other hand, only striving to build capacity to absorb an impact presents a risk of overly conservative planning. This tension relates back to the fundamental conflict between present needs and future risk. Therefore, to address these issues, each assumption must be critically examined.

4.1.1 The importance of general preparedness

Resilience theory assumes preparation best addresses the threats posed by a hazard. The importance of adaptation encourages generality of these plans. The Resource Management Act clearly subscribes to this ideal, obliging councils to write objectives, policies and methods in relation to hazard management, while also allowing them the flexibility to choose which hazards to prepare against and to what degree. This flexibility to adapt to local challenges, while normally applauded by resilience theory, has arguably caused inadequate provisions in relation to liquefaction in every region examined but Canterbury. Due to being relatively unknown, especially before the Christchurch earthquakes, liquefaction has simply failed to be addressed even in areas where it poses a high risk.

While the law currently serves as a guide to officials in implementing the management of liquefaction hazards, its generality constrains effectiveness. Most council plans have broad hazard management policies with almost no methodologies in place to implement them. Hamilton City Council's current plan fails to even outline which hazards the district may be susceptible to, almost completely defeating the purpose of addressing hazards in the Plan at all.

Because liquefaction requires different mitigation methods from other risks associated with earthquakes, preparing generally for an earthquake will not adequately prepare a region against liquefaction. Even the Building Code only cites earthquake as a hazard, which is the regulation some would argue to be the best measure at implementing liquefaction mitigation. The Building Act fails this test to a greater degree, with liquefaction excluded from its definition of natural hazards. This gap in the law likely highlights absence of demand. Because most of New Zealand has not experienced liquefaction, despite being

vulnerable to its effects, the hazard is considered low risk. Only Canterbury, having experienced the detriments of liquefaction, sees present need in establishing a specific, and therefore effective, plan.

General preparedness is indeed important to building resilience, but specificity is also crucial. Adaptation should not be used as an excuse to create overly broad strategies which are difficult to implement. Minimum standards would allow for more widespread implementation of the engineered mitigation strategies against liquefaction. Furthermore, methodologies are potentially the most important aspect of a strategy as they outline the actions which must take place to implement a policy and achieve an objective. Terms such as "mitigate" and "assess" are useless if crucial information like when, where and how is not addressed.

4.1.2 The effectiveness of intelligent planning

Resilience theory assumes all hazards could be mitigated by developing in locations where hazards pose less risk. Indeed, planners and engineers alike call for planning to be used to minimise liquefaction risk. Planners should endeavour to plan developments away from high-risk areas and if doing so is unavoidable, engineering methods should be implemented to mitigate.

Liquefaction poses several challenges to this key tenet of resilience theory. It is difficult and costly to survey at a local level, but regional-scale risk maps are too broad to implement any realistic planning. Because liquefaction specifically occurs on flat land, which is often optimal for development, planning to avoid it goes against common sense. Furthermore, alternative areas to develop, like hillsides, pose a much higher risk of potentially fatal landslides and rock-fall during an earthquake. Therefore, the need to avoid liquefaction is often outweighed by the need to develop in the safest and most cost-effective manner possible.

Where avoidant planning has been implemented, such as the Christchurch red zone, the method was praised as a prudent example of resilient planning as engineers and planners agreed the land could not be rehabilitated for redevelopment.[41] However, this was not without its problems. The residential red zone comprised nearly 8000 houses, so leaving it undeveloped has created a housing shortage and encouraged urban sprawl during the rebuild.[42] Thus, the Christchurch community suffered a loss of social cohesion, farmland and environmental integrity.[43] Avoiding development on hazard-prone land is a

41 Z Zhang "Mitigation of Damages to Residential Buildings Caused by Liquefaction Induced Settlement in Christchurch" (ME Thesis, University of Auckland, 2015) at 2.

42 Kim, above n 7, at 11.

43 At x and 1.

conservative planning method that can create social and economic issues which are problematic to downplay in the name of risk management.

4.1.3 "Mitigation" as a tool

Resilience assumes mitigation to be an effective tool to achieve desirable outcomes. Nevertheless, although mitigation is frequently mentioned in the law and literature, it is rarely defined. In this way, it seems to share with resilience an aspirational quality. More frequently, mitigation is discussed as a solution without acknowledging the fact that it can be a slow and demanding process.

Ground compaction, de-watering and reinforcement are often the most reliable mitigation techniques to liquefaction, yet take time and are financially costly. Because liquefaction has lower risk of contributing to fatalities than other earthquake hazards, it is a hazard largely of financial implication. This factor must be carefully considered by lawmakers so mitigation methods do not become uneconomic and therefore burdensome. An unqualified requirement for the mitigation of liquefaction is likely to unnecessarily increase building costs and even exacerbate housing shortages.

4.1.4 Education and awareness as a strategy

Resilience assumes education and awareness of a hazard causes a community to be less prone to that hazard. Educated officials implement more effective hazard management strategies, while aware laypeople create demands for these strategies and may implement smaller projects to build hazard resilience in locales and private property. Effectively, education is seen as the first step in creating preparedness.

Of all the problems raised by the law, awareness of liquefaction appears least glaring. Arguably, the absence of liquefaction's mention in the Building Act and many council documents could cause the hazard to be overlooked but this is an unrealistic assessment. Most, if not all, engineers and planners are aware of liquefaction risks, especially in light of Canterbury's experience of the impacts. The Ministry of Business, Innovation and Employment has a non-binding but extremely informative liquefaction planning guide for all officials to refer to. Liquefaction risk is also listed on property land information memoranda (LIMs) and therefore accessible to those potentially directly impacted by its effects.[44] However, this does not mean education cannot cause issues in liquefaction management.

44 L Timar, A Grimes and R Fabling *That Sinking Feeling: The Changing Price of Disaster Risk Following an Earthquake* (Motu Economic and Public Policy Research, Wellington, 2014) at 5.

The biggest issue with using education as a solution is one of liquefaction's greatest challenges: it cannot easily be prepared for retroactively. Many buildings can be reinforced against the shaking of an earthquake, but retrofitting buildings with liquefaction mitigation remains prototypical and highly costly. Therefore, while educating officials remains an important strategy in Christchurch and future developments, using it to tackle liquefaction risk within existing urban New Zealand remains highly unsatisfactory.

Furthermore, raising awareness amongst the community raises some equality issues. The effectiveness of LIM notifications in warning renters of a land hazard has been questioned. Renters are less likely to read a LIM for properties they do not own, often because of the costs involved in obtaining one.[45] Therefore, it is arguable they are most at risk of being disturbed by liquefaction, and suffering property damage from ejected debris. As this issue is rooted in socio-economic disparity, it largely raises concerns of environmental justice.

4.1.5 The goal of "bouncing back"

Resilience assumes that "bouncing back" in the aftermath of a hazard is an aspiration. However, this assumption is often counterproductive, taking attention away from preventative response, and encouraging communities to return to the status quo.[46] This mindset is especially problematic when considering that liquefaction risk may increase over multiple events.

Bouncing back from a hazard is almost contradictory to building capacity to absorb a hazard — if enough capacity is built there should be no more than minor effects, and therefore no need to bounce back. While this idea may be irresponsible in practice, councils often appear to consider effective response after a hazard to be equally as effective as planning preventative measures against it, which is more problematic. Effectively, ideas of bouncing back discourage adequate preparation. Despite all the problems proactive planning against liquefaction may bring, reliance on post-event response is likely the least ideal planning strategy.

New Zealand has witnessed the issues that arise with relying on "bouncing back" in response to liquefaction as a primary management tool. In September 2010, Christchurch suffered an earthquake which saw minor liquefaction impacts. The community responded by working together to clean up liquefied

45 C Smith and B Coombes "Washing Their Hands of It? Auckland Cities' Risk Management of Formerly Horticultural Land as Neoliberal Responsibilisation" in T Taşan-Kok and G Baeten (eds) *Contradictions of Neoliberal Planning: Cities, Policies, and Politics* (Springer, Dordrecht, 2012) 133 at 142.

46 Davoudi, above n 40, at 302.

debris, assess damage and rebuild with small improvements.[47] While this was hailed as a strong example of resilience, the February 2011 earthquakes quickly overturned this work with far greater and more widespread damage, a significant proportion of which was created by liquefaction. It was only after learning from this devastation that Christchurch created a robust planning framework which far outperforms that of other regions.

Bouncing back should be considered the least effective assumption of resilience to rely upon, because the tension between present and future needs dissolves in the wake of an earthquake. The present requires rebuilding, while the future requires lack of repetition of the event. These two needs no longer conflict, and could strengthen one another. However, proper foresight is required for immediate and effective redevelopment that also avoids hazards. Apart from Christchurch, council plans are deficient in this regard, failing the needs of both communities.

4.2 Discussion

An exploration of the interface between law and theory in relation to liquefaction planning demonstrates the complexity planners and lawmakers face in implementing ideals of resilience theory. While resilience is a helpful concept by providing an admirable aspiration to work towards, it relies on several assumptions which create problems in relation to liquefaction. These assumptions are particularly apparent when examining written planning law. It is proposed that the problems found in the law exist not solely from ignorance or lack of political will, but also from the contradictions and huge challenges created from uncritically pursuing resilience outcomes.

Liquefaction is a hazard which poses many challenges. The hazard is best managed through sound planning, yet affects land that is otherwise ideal for development and which poses the least danger from other earthquake hazards. Furthermore, the property New Zealand wishes to protect most is already built. Awareness of the issue often fails to help the most vulnerable and struggles to be of use, because mitigation is often uneconomic. Liquefaction risk may also increase over time, making long-term planning responses critical. Writing optimal substantive policies against the hazard is therefore extremely taxing and resource-intensive, which is likely why so much of the law is silent on the issue. While not ideal, ignoring liquefaction as relatively low risk so that efforts may be focused on more pressing needs is understandable from a practical perspective.

47 WSA Saunders and JS Becker "A discussion of resilience and sustainability: Land use planning recovery from the Canterbury earthquake sequence, New Zealand" (2015) 14(1) International Journal of Disaster Risk Reduction 73 at 77.

However, while this gap is understandable, the law can and should be improved. Appreciating the complexities involved, this article does not serve to propose any substantive additions to the law. Instead, improvements to hazard law's form could create much-needed critical engagement of the theory, and therefore better outcomes. The concept of resilience should be used to assist in guiding the law, but must be understood for what it is — an aspiration, not a solution. Applying resilience in the law necessitates laying out the methods demanded by the Resource Management Act to implement policies and objectives. Well-considered methods are a vital tool in putting planning ideals like resilience into practice, and provide transparency to stakeholders. It must be acknowledged that resilience demands trade-offs and is inherently conservative. When a choice is made in favour of hazard management strategies over development or vice versa, providing a comprehensive justification would compel lawmakers to critically engage with the concept of resilience, like what is found in the Canterbury Regional Policy Statement.

5. CONCLUSION

This article has explored the legal response to liquefaction hazards across New Zealand to better understand hazard management discourse more generally. The key finding is a disconnect between what planning theory advocates and what lawmakers are enacting, creating dangerous gaps which threaten a repetition of the liquefaction experienced during the Christchurch earthquakes. Problems with existing law creating inequitable outcomes in the present were also found. While resilience theory emphasises the importance of preparedness and minimising future risk, it often fails to appreciate the demands this makes of the present population. While law attempts to mediate these two needs, trade-offs must be made. As has been discovered, it is rare to make a compromise in relation to liquefaction that does not entail high costs.

The inherent problem with resilience theory is not issues with its vision, but the lack of critical engagement surrounding the concept. For this reason, the concept of resilience is a muddled and sometimes contradictory idea, based on assumptions that create challenges in practice. This is problematic when it is used to guide the law. Therefore, it is proposed that the law's form be changed in order to best address liquefaction and, in turn, other hazards more generally. Once resilience is engaged with, it invites justification of trade-offs and recognition of gaps in strategy, but this leads to transparency. Resilience should be seen for what it is: a vision, not a solution. Therefore, processes in the form of methodology must be considered just as important as the policies and objectives they aim to achieve.

It is acknowledged that this solution may not be the most satisfactory as it

is receptive to failure and compromise. However, this is simply reflective of the many challenges and complexities inherent to addressing liquefaction. The most sensible decisions might often be of minimal action towards addressing liquefaction due to the low risks it presents, because any other action would serve to be uneconomic or overly burdensome to present needs. The only solution to this problem, therefore, is transparency. Community needs should not be shelved for overzealous liquefaction mitigation, nor should officials become complacent with evaluating risk and the various management options. While there are no right answers to satisfy these difficult questions, there is either effective or ineffective law to help enact the solutions decided upon.