Cost benefit analysis:

Plan change 47 – Upper Hutt

12 April 2022

SENSE PARTNERS
DATA LOGIC ACTION

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Key points

We test the impacts of a suite of natural hazard policies…

- We assess the costs and benefits of a suite of policies in Proposed Plan Change 47 that have the objective NH-O1:

  "Subdivision, use and development with the Natural Hazard Overlays does not increase the risk to life and property"

- The proposed policies span:

  NH-P1 – Identification of Natural Hazards
  NH-P2 – Least Hazard Sensitive Activities with the Mangaroa Peat Overlay, High Slope Hazard Overlay and Wellington Fault Overlay
  NH-P3 – Hazard Sensitive and Potentially Hazard Sensitive Activities within the poorly constrained or the uncertain constrained areas of the Wellington Fault Overlay
  NH-P4 – Hazard Sensitive and Potentially Hazard Sensitive Activities within the well-defined or well-defined extension areas of the Wellington Fault Overlay
  NH-P5 – Hazard Sensitive and Potentially Hazard Sensitive Activities within the Mangaroa Peat Overlay
  NH-P6 Earthworks in the High Slope Hazard Overlay
  NH-P7 Subdivision where additional building platforms are created in the High Slope Overlay

… Benefits exceed costs for the Wellington fault policies

- There are a range of uncertainties. Likely costs include higher construction costs for new builds and alterations and foregone development within the revised zone.
- Primary benefit is reduced exposure to fault rupture impacts on health and safety, the local economy and building stock. We find benefits likely outweigh costs.

… Benefits exceed costs for the Mangaroa Peatlands

- There are a range of uncertainties. Costs include higher construction costs for new builds and the potential for foregone development opportunities.
- Benefits include lower settlement risk and reduced risk exposure to properties in the identified hazard area. We find benefits likely outweigh costs.

… Benefits exceed costs for the High-slope hazard

- There are a range of uncertainties. Costs are higher construction costs for new builds and are lower than for the Wellington Fault zone and Mangaroa Peatlands.
- Benefits are reduced risk of property and are likely to exceed costs.

Summary

- Across all policies, over a 20-year period, we find benefits of $18,219,128 that exceed costs of $6,683,058. Net benefits are $11,536,070 in 2022 prices.
- Our assessment finds a benefit-cost ratio of 2.73, suggesting value for money.

1. Overview

1.1. Context

In March 2022, Upper Hutt City Council (UHCC) approached Sense Partners to conduct a cost-benefit analysis of a proposed change to the district plan (plan change 47). This report is prepared pursuant to Section 32 of the Resource Management Act 1991 to support Proposed Plan Change 47 to the UHCC District Plan.

This proposed plan change is in response to a district wide geotechnical assessment which identified two new natural hazards. This includes identification of peatlands unsuitable for development, and slopes at high risk of landslides. In addition, an earthquake fault trace survey has improved understanding of fault locations and areas likely to be impacted by a fault rupture. We assess the impacts of the policies on these 3 hazard features.

What changes are proposed

- **Wellington fault** – The existing 40m wide fault band is being replaced with a variable width fault band. Impacts on land use vary between sections of the fault. Some development forms will be strongly discouraged and , will be subject to resource consent.
- **Mangaroa peatlands** – A new peatland has been identified which is expected to provide poor ground conditions for development. Future subdivision will need to demonstrate an ability to overcome this issue through the resource consent process.
- **High slope hazards** – A new slope overlay is being added to the plan, identifying where the ground slope poses a greater than "low" hazard of landslips. Future development will need to demonstrate and ability to overcome this issue through the resource consent process.

Why these changes are being proposed

The objective of the proposed changes is to ensure that development in Upper Hutt does not increase the risk to life or property arising from natural hazards. This necessitates preventing some types of sensitive development from occurring in some areas. In other areas and for less sensitive activities, greater oversight is required through the resource consent process to ensure no increased risk.

These changes are in line with best-practice guidance

The proposed changes to the fault band have been developed using risk-based approach guidance issued by the Ministry for the Environment. This guidance uses three factors to establish appropriate land use on or near a fault line. These are:

- **Fault recurrence interval** – The frequency, measured in years, with which the given fault is expected to rupture.
- **Fault complexity** – A narrow, well defined fault line poses a greater risk than one more disbursed.
- **Building importance category** – A ranking of activity uses based on their sensitivity to hazards and the importance of their endurance.

1.2. Natural hazards

Why we are conducting a cost benefit analysis

The purpose of this cost-benefit analysis to assess the trade-offs involved in making the proposed amendments to the district plan. This can help UHCC balance the need for hazard management and risk minimisation with the desire to develop land around the city for best economic uses. Achieving this balance will help UHCC to enhance the welfare of residents.

Hazard management brings benefits with trade-offs

The benefits to hazard management are primarily in the form of reduced risk to life. The benefit may not be realised on a day-to-day basis but will mean that in the event of a disaster, fewer people are killed or injured. This will also mean reduced damage to property and infrastructure networks, contributing to a more resilient city.

The cost of the proposed changes primarily lies in the form of the opportunity costs of foregone development. The fault runs through, and the peatland lies on, undeveloped land near the city. The slopes affected by landslip risk border the city on all sides. If not for these hazards, this land would have a high value in being used for residential purposes, and other urban activities.

By placing restrictions on the use of the land, UHCC may lower the risk to life and property but at the cost of this development. Some land may have all future development prohibited. Other land will allow development, but subject to costly resource consent processes and engineering design mitigations, making it less economic to develop.

By preventing development, we miss out on its benefits

Development can bring benefits. The primary benefit is to expand the housing stock, which can help to lower the cost of rent and therefore the cost of living. An expanded housing stock can also improve the quality of the rental stock available, as well as the quality of stock available for purchase. Many social ills associated with expensive and poor-quality housing, such as overcrowding and sickness, can be alleviated through an increase in supply.

Development can also expand commercial activities, bringing economic growth to the area. Commercial activities can provide employment opportunities, as well as valuable amenities to the local community. Development of an area can also support the provision of community facilities and amenities through a larger rate base.

Development may simply occur elsewhere at little extra cost

Placing restrictions on the use of some land may prevent development occurring in that area. However, the development, and all its associated benefits, may nevertheless occur in areas nearby. The net impact of displaced development may only be minor. For example, if displaced to land further away from the central city, this may entail some marginally higher transport costs.

Development may also be accommodated within the existing urban footprint unaffected by hazards. Higher density development has many additional potential benefits. While it we

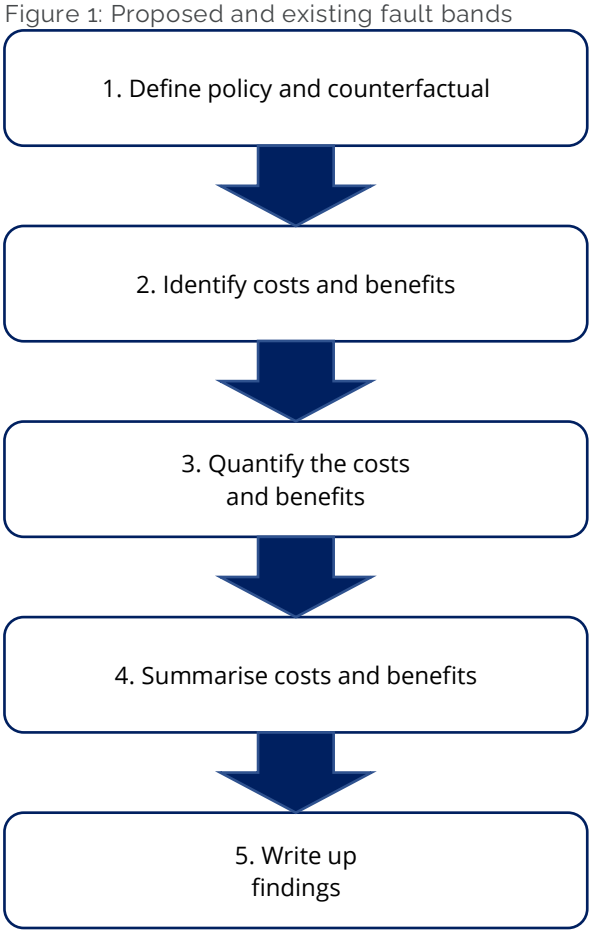
would expect it to come at a higher construction cost, it may not be more expensive than building on steep slopes or poor soils identified as hazards. Regardless of amendments to the plan, the market will demand houses with an acceptable level of structural integrity and endurance.

To understand whether the proposed changes are a net positive, we seek to estimate and compare these costs and benefits of the proposed changes. If the benefits outweigh the costs, then we can consider the proposed plan change to be welfare enhancing.

1.3. A stage CBA process

To carry out our assessment, we work through a staged process for our cost-benefit analysis, that we outline in Figure 1. To begin, we set out the policies against the counterfactual of doing nothing. Then we identify the costs and benefits before quantifying the costs and benefits. Finally, we summarise and compare the costs and benefits, discounting future costs and benefits.

Figure 1: Proposed and existing fault bands



Source: Sense Partners

2. Scope of policy

2.1. Scope of the new policy: Plan change 47

Proposed Plan Change 47 is intended to amend the District Plan to reflect recently identified natural hazards. This includes an improved understanding of where the Wellington Fault is located, the identification of peatland areas, and identification of high slope hazard areas.

For our CBA, Plan Change 47 forms the new policy while doing nothing is the counterfactual.

Each identified hazard will impact land use in different ways, depending on the nature of the hazard. Different land uses are categorised by how sensitive they are to hazards. These hazard sensitivity categories are used to translate the impact of each hazard onto land use. Table 1 below provides a high-level summary of these hazard sensitivity categories. This is indicative for the purposes of this cost-benefit analysis.

Table 1: Different land uses typically have different hazard sensitivities
Stylised breakdown of activities by hazard-sensitivity

Hazard sensitivity	Activities
Hazard-sensitive activities	Residential and community facilities
Potentially hazard-sensitive activities	Commercial and industrial facilities
Less hazard-sensitive activities	Non-habitable accessory structures and parks facilities

Source: Upper Hutt City Council Plan proposed plan change 47

2.2. Wellington fault

Upper Hutt City Council and Greater Wellington Regional Council engaged GNS Wellington to conduct an earthquake fault trace survey of Upper Hutt City. This has improved understanding of fault locations and areas likely to be impacted by a fault rupture.

The fault is currently marked as a 40m wide band in the District Plan. In the Operative District Plan, any habitable building or structure to be built within the band is a discretionary activity. and subject to a resource consent application, triggered by the matters in Table 2 below.

Table 2: The Wellington fault triggers a resource application
Matters for consideration in resource consent applications

Matters for consideration
The accuracy of information relating to the location of the fault
Potential effects of an earthquake given the proposed nature and scale of the building
The extent to which the building complies with Clause B1 Structure of the NZ building code.
The measures proposed to avoid, remedy, or mitigate the effects of an earthquake.

Source: Upper Hutt City Council Operative District Plan

This plan change will replace the existing fault band with a new fault band. This band will vary in width between 40m and 300m and will include five different fault areas. These classifications, set out in Table 3 below, reflect the precision with which the fault has been identified in each area.

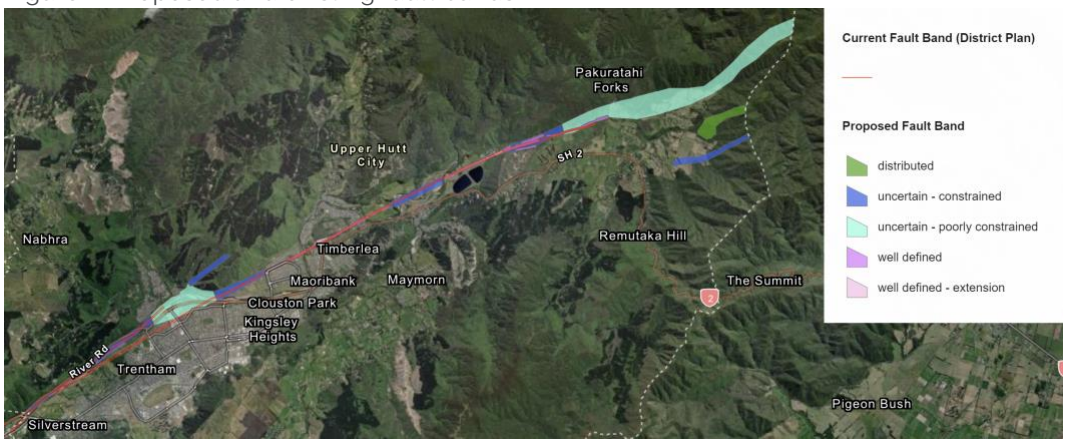
Table 3: Proposed fault band Areas and related activity restrictions

Areas	Restrictions
Distributed	No apparent restrictions
Uncertain - constrained	New buildings falling under "Potential Hazard-Sensitive Activities" and "Hazard-Sensitive Activities" are restricted-discretionary. Small extensions to gross floor space (25m^2 – 40m^2) are permitted. "Less hazard-sensitive activities" are permitted.
Uncertain - poorly constrained	
Well defined	New buildings falling under "Potential Hazard-Sensitive Activities" and "Hazard-Sensitive Activities" are prohibited. Extensions to existing buildings are restricted-discretionary. "Less hazard-sensitive activities" are permitted.
Well defined - extension	

Source: Upper Hutt City Council Plan change 47

Figure 2 below shows the full scope of changes to the fault band across the district.

Figure 2: Proposed and existing fault bands



Source: Upper Hutt City Council Plan change 47

These changes can be summarised as follows:

- Increase the land area subject to fault related restrictions.
- Move from uniform to varying restrictions and requirements on land use in the fault band.
- In uncertain fault areas, retain the need for resource consent for new developments and large extensions to existing buildings, while permitting small extensions without resource consent.

- In well-defined fault areas, move from allowing development subject to resource consent to strongly discouraging new development and subjecting extensions of existing properties to resource consent.

Table 4 below provides a summary of changes to matters for consideration in resource consent applications.

Table 4: Proposed matters for consideration – Fault Band

Activity	Matters for consideration
Additions to a building in the well-defined or well-defined extension areas	1. The change to risk-to-life because of additions, 2. The location of additions relative to the fault line and any mitigation measures.
New "hazard-sensitive" and "potential hazard-sensitive" activities in the uncertain - poorly constrained and uncertain - constrained areas	1. The ability for the building to maintain life safety in an earthquake. 2. The ability for the building to remain structurally sound because of an earthquake 3. The location of the building relative to the fault line and any mitigation measures to reduce the impacts from fault rupture.

Source: Upper Hutt City Council Plan change 47

Interactions with existing hazard overlays

Both the Wellington fault line and the Hutt River run through the Hutt Valley. Although the river does deviate, the two hazards do coincide along much of the length of the fault through Upper Hutt. This means that much of the land subject to proposed restrictions is already subject to existing hazard restrictions related to the Hutt River flood hazard area.

Table 5: Existing matters for consideration – flood hazard area

Activity	Matters for consideration
Buildings and structures regardless of purpose erected in the flood hazard area.	1. Whether the proposed development would increase the level of risk to safety of individuals 2. The effects of earthworks or infilling.

Source: Upper Hutt City Council Operative District Plan

Comparing the matters for consideration in Table 4 and Table 5, both emphasise the need to avoid increasing risk to life. Those related to the fault band are more earthquake specific, but it is unclear that additional onerous requirements are being proposed. The additional consenting cost caused by the enlargement of the fault band may be small.

An example of this is shown in Figure 3:Figure 3 below. Here, the proposed expanded fault band applies resource consent requirements to a greater area than the existing band. However, the Hutt River flood hazard area captures almost all this extended area. The flood hazard requires resource consent approval for development.

Figure 3: Example of extensive overlap with the flood hazard area

Source: Upper Hutt City Council Operative District Plan

Figure 4 below gives an example of the proposed uncertain – poorly constrained overlay overlapping the flood hazard zone. Here the addition of the wider earthquake band does impose resource consenting conditions on an area not already subject to them.

Figure 4: Example of partial overlap with the flood hazard area

Source: Upper Hutt City Council Operative District Plan

Some of this land is zoned open space, some business industrial, and the remainder residential. The addition of resource consenting requirements in an area with none currently may add significant cost to development in this area.

2.3. Mangaroa peatlands

The geotechnical assessment carried out by Coffey Geotechnical Engineers has identified a "swamp / peat area" in Whitemans Valley. The soil in this area is expected to be soft and organic rich which may result in ground settlement. This hazard may occur even in the

absence of an earthquake. This is the first inclusion of peatlands as an identified hazard with implications for land use.

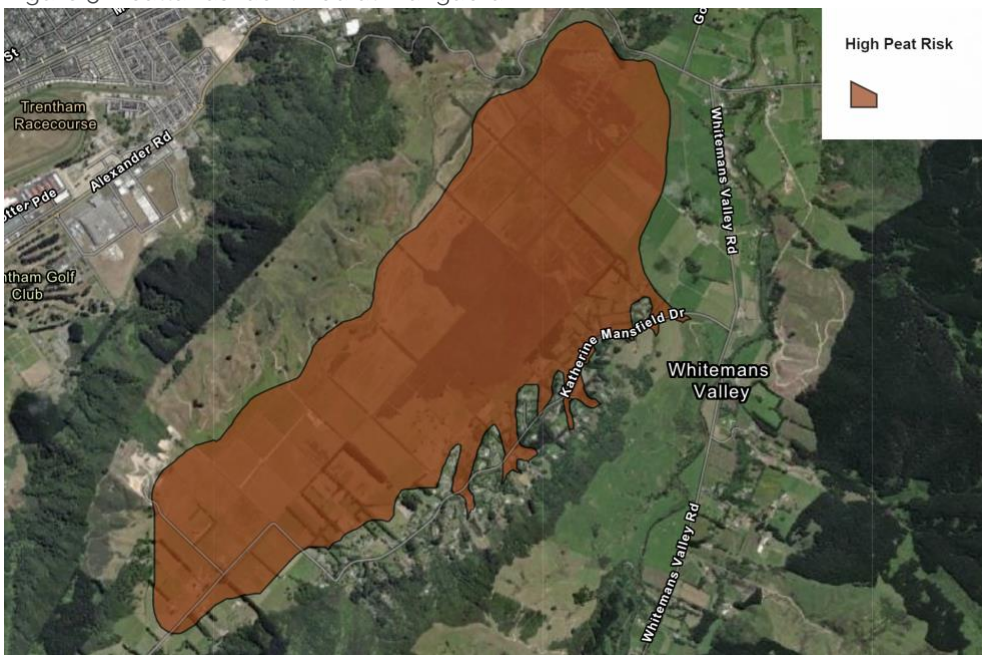
Table 6: Proposed Activity restrictions in the identified peatland

Areas	Restrictions
High peat risk	New buildings falling under "Potential Hazard-Sensitive Activities" and "Hazard-Sensitive Activities" are restricted-discretionary. "Less hazard-sensitive activities" are permitted.

Source: Upper Hutt City Council Plan change 47

Figure 5 below shows the identified high peat risk area in Whitemans valley.

Figure 5: Peatlands identified at Mangaora



Source: Upper Hutt City Council Plan change 47

Table 7 below provides a summary of changes to matters for consideration in resource consent applications.

Table 7: Proposed matters for consideration - Peatland

Activity	Matters for consideration
"Potentially hazard-sensitive" and "hazard sensitive" activities (including subdivision for these purposes).	It can be shown subdivision will not increase property damage risk due to the building being on good ground. A geotechnical assessment of soil conditions shows that liquefaction is unlikely to occur in an earthquake, or appropriate mitigation measures are included in the building design to reduce the likelihood of damage.

Source: Upper Hutt City Council Plan change 47

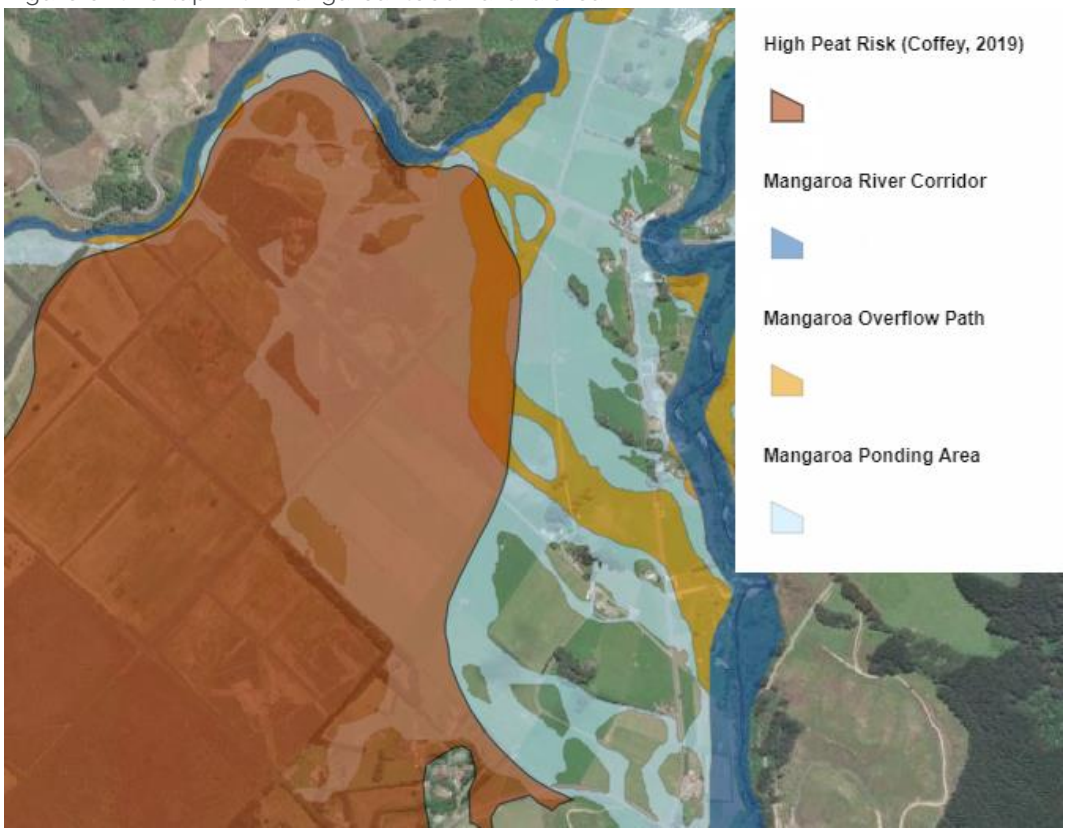
The change this represents can be summarised as follows:

- Subject all development to resource consent requirements in the identified Peat Area.

Interactions with existing hazard overlays

The peatland overlaps the Mangaroa ponding area and overflow path identified as natural hazards in the operative district plan. These reflect the risk of flood posed by the nearby Mangaroa river. This means that part of the proposed peatland overlay is already subject to resource consent requirements.

Figure 6: Overlap with Mangaroa flood hazard area



Source: Upper Hutt City Council Operative District Plan

Resource consent considerations extend to site access. Access to any hypothetical development on the peatland area would likely build on existing road corridors. These include Whitemans Valley Road and Wallaceville Road, with the latter providing the most direct access to the CBD. Both roads interact with the ponding area and overflow paths, and Wallaceville Road crosses the river corridor.

Resource consent considerations include suitability of access as an evacuation route in a 1-in-100-year flood event. As both existing roads run through the flood hazard zone, their utility as an evacuation route may need to be established through expert studies. As a result, it is likely that any subdivision occurring on the peatland, regardless of proposed changes, would nonetheless be subject to the resource consent process. Considering this, the additional cost to implementing the proposed peatland overlay may be small.

2.4. High slope hazard

The geotechnical assessment carried out by Coffey Geotechnical Engineers has also identified areas of high slope hazard. These areas are at risk of landslips caused by high rainfall and earthquakes. The areas identified are those with a slope gradient above 26 degrees, which is considered a low hazard for instability.

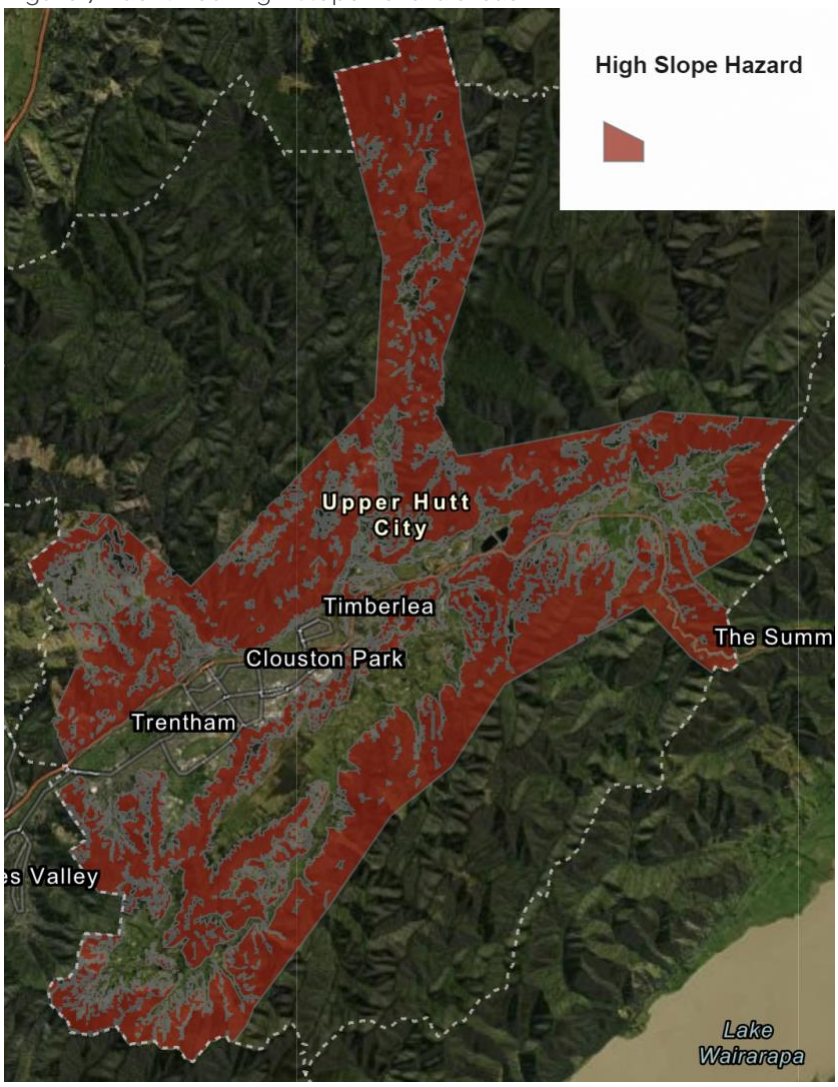
Table 8: proposed Activity restrictions in High Slope hazard areas

Areas	Restrictions
High slope hazard	Earthworks or subdivision for a building platform for the purposes of a "potentially hazard-sensitive" or "hazard-sensitive" activity.

Source: Upper Hutt City Council Plan change 47

Figure 7 below shows the identified high slope hazard area in Upper Hutt.

Figure 7: Identified High Slope hazard areas



Source: Upper Hutt City Council Plan change 47

Table 9 below provides a summary of changes to matters for consideration in resource consent applications.

Table 9: Proposed matters for consideration - Peatland

Activity	Matters for consideration
Earthworks for a building platform (and subdivision for this purpose)	1. A geotechnical assessment confirms that proposed works will not unacceptably increase the risk from slope instability to people and buildings. 2. Earthworks will not increase the risk of slope failure at adjacent sites.

Source: Upper Hutt City Council Plan change 47

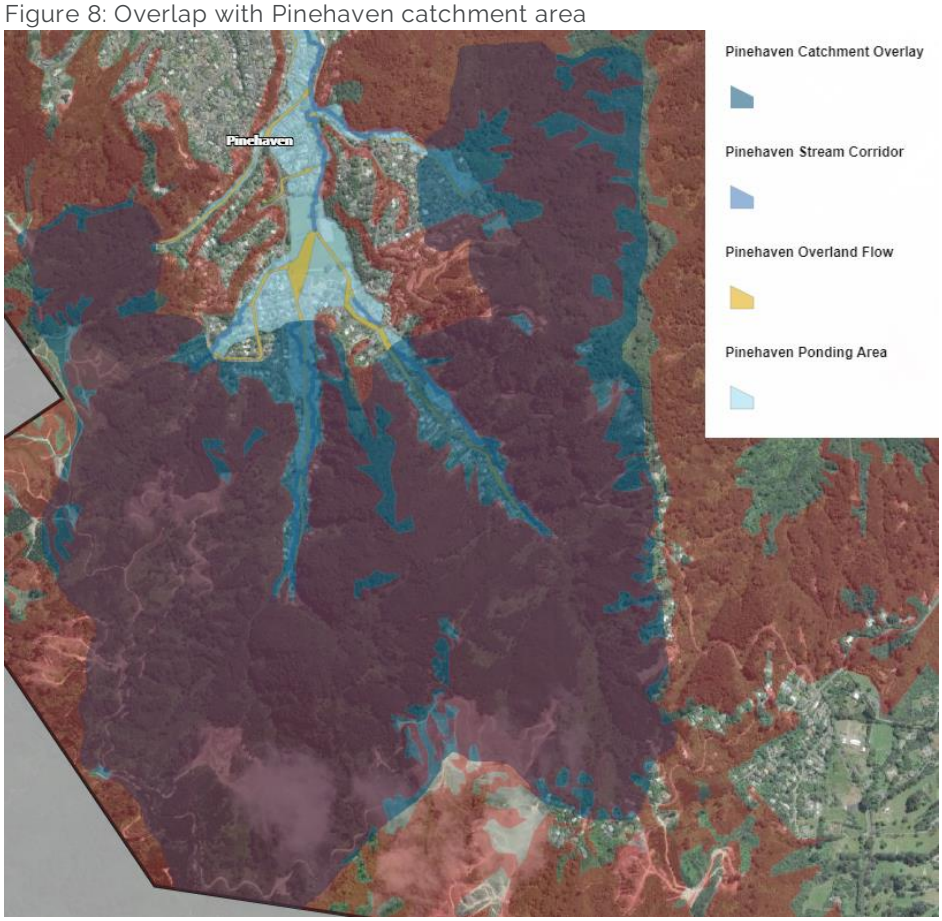
The change this represents can be summarised as follows:

- Subject all development to resource consent requirements in high slope hazard areas.

Interactions with existing hazard overlays

Throughout the length of the Hutt River, there are some minor overlaps between the Hutt River flood hazard area and the high slope risk area. The most significant point of overlap is that with the Pinehaven catchment, shown in Figure 8 below.

Figure 8: Overlap with Pinehaven catchment area



Source: Upper Hutt City Council Operative District Plan

Table 10: Existing matters for consideration – Pinehaven Catchment

Activity	Matters for consideration
Any building for any purpose	1. Achieves hydraulic neutrality 2. Expert report confirming hydraulic neutrality

Source: Upper Hutt City Council Operative District Plan

3. Identifying costs and benefits

Before quantifying the costs and benefits of the proposed changes to the District Plan to address natural hazards, we first identify the relevant costs and benefits of the proposed changes.

3.1. Costs

On the cost side, there are at least three key costs: (i) increased costs of construction, (ii) foregone development and (iii) underutilised infrastructure we set out in Table 11.

Table 11: Description of expected costs

Cost	Description
Increased cost of construction	The need to mitigate the effects of slope instability, liquefaction, and threat to life through engineering solutions may increase the cost of construction in affected areas.
Foregone development	Where the cost of mitigation is high, development of the land for Hazard Sensitive and Potentially Hazard Sensitive activities may be unfeasible. This development may occur elsewhere, or not at all.
Underutilised infrastructure	Depending on the state of infrastructure in the affected areas, there may be existing excess capacity which cannot be utilised through greater development of the area.

Source: Sense Partners

3.1.1. Increased costs of construction

Wellington Fault

Increased costs of construction can occur for both new builds and existing dwellings. Within the fault zone Natural Hazards Policy 4 seeks to:

> "Avoid the construction of new buildings or subdivision associated with, or the of establishment, of Hazard Sensitive and Potentially Hazard Sensitive Activities within the well-defined or well-defined extension areas of the Wellington Fault Overlay, unless it can be demonstrated that:
>
> (a) The activity or subdivision has a critical operational and functional need to locate or occur within the High Hazard Areas and locating or occurring outside the High Hazard Areas is not a practicable option; and
> (b) The activity or subdivision incorporates mitigation measures that demonstrate that risk to people, and property is avoided.
> (c) There is no increase in risk to life or buildings on adjacent properties from the proposed works."

This suggests new dwellings are less likely, but we will need to assess the likelihood of new dwellings in the fault zone and the cost of alterations to existing dwellings.

Costs should include not just build costs, but the costs of geotechnical specialists and the costs of required fees and services included consent fees.

Mangaroa Peatlands

Construction costs will be impacted for new builds in Mangaroa. Natural Hazards Policy 5 says:

> "Provide for subdivision that results in the creation of vacant allotments in the Mangaroa Peat Overlay provided:
>
> (a) It can be demonstrated through a geotechnical investigation that the subdivision will not increase the risk of damage to property due to the building platform being located on good ground; or
> (b) A geotechnical assessment shows that there is the ability for appropriate mitigation options to be incorporated into the design of a future building to reduce the likelihood of damage as a result of poor ground conditions on the identified building platform.

Documentation on the hazard suggests variety across the area.[1] Some regions will be impacted by other hazards (flood plain). Other areas will be badly impacted. Other areas will require deep geotechnical assessments to better understand what is needed:

> "For most of the Mangaroa Area, soft ground is not anticipated to be a concern, however standard investigations to confirm bearing capacity and ground profile should be undertaken prior to the construction of any structures."

But large-scale development in Mangaroa, even in the absence of additional construction costs is far from guaranteed. So we need to assess the likelihood of development prior to assessing increased in construction costs.

Since there are relatively few existing properties in Mangaroa, and alterations are unlikely to be a primary contributor to settlement risks, we set to one side any increase in the costs of altering existing properties in the hazard.

Geotechnical assessments may also lower other costs of the construction process.[2]

High slope Hazard

Costs of construction will increase for properties on high-slope areas. These now include cots of geotechnical assessment and council fees.

The number of existing dwellings on the high-slope hazard area is small relative to the existing housing stock in Upper Hutt. So, it will be key to assess the number of dwellings likely to be impacted when assessing increased costs of construction in the high slope area.

[1] See Coffey Services 2020.
[2] See https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/practice-advisory-17/

3.1.2. Foregone development

Wellington Fault

The limits on new building within the fault area is clear from the Natural Hazards Policy 4. Existing landowners have lost the right to build under most circumstances. However, the question arises on the extent to which new development would be likely to take place and the benefits and costs of subsequent development.

Mangaroa Peatlands

Assessing the extent of development in Mangaroa, in the absence of Natural Hazard policies is one of the critical questions for the cost-benefit analysis.

On the one hand, the area represents low-cost land that is in principle near to the city centre.

But this must be traded off against the lack of existing amenities, the likelihood of low-quality access to public transport and the rail connection to Wellington that is highly valued by Upper Hutt residents.[3] And now, construction costs associated with large scale developments should be anticipated to be much larger than before.

Foregoing development raises the question of whether much lower development yield in Mangaroa would have broader impacts, on the level and cost of housing across Upper Hutt. We note that Mangaroa is not identified in the 2019 Housing Business Assessment as a significant site of feasible supply so do not conduct further investigation on broader impacts on house prices across the district. Many other sites provide sufficient capacity based on the 2019 assessment.

High Slope hazard

While the high slope hazard covers a large area, the cost of subdividing and then developing this land limits the extent to which foregone development will impact the area spanned by the high slope hazard. Any development of the land would need to yield a premium sufficient to cover the additional costs laid out in Natural Hazard Policy 6:

> "Provide for earthworks in the High Slope Hazard Overlay, where:
>
> a. A geotechnical assessment confirms that the proposed earthworks will not unacceptably increase the risk from slope instability to people, and buildings; and
> b. The earthworks will not increase the risk of slope failure at adjacent sites.

Subdivision is explicitly addressed in Natural Hazard Policy 7 – Subdivision where additional building platforms are created:

> "Provide for subdivision that creates additional building platforms in the High Slope Hazard Overlay where:

[3] See Sense Partners 2019.

c. A geotechnical assessment confirms that the site is suitable for subdivision, use and development and that the risk from slope instability can be avoided, remedied, or mitigated.
d. The subdivision will not increase or accelerate land instability on adjoining properties.

Any assessment of the impact of foregone development will need to first assess the likelihood in the case of the "do nothing" alternative.

3.1.3. Underutilised infrastructure

On potential cost of the proposed Natural Hazard policies is to shift the intensity of public assets.

For large shifts in identified hazards, this could mean some assets, private housing, public roading and three water infrastructure are stranded, unable to be used for their intended purpose.

But at the margin, changing density of dwellings could mean some assets are not utilised to their full intensity. Other assets may be required to accommodate population growth in other locations.

We briefly examine infrastructure utilisation to test likely size of costs from shifts in patterns of infrastructure use.

3.2. Benefits

Coffey Services 2020 describes the risk from three natural hazards within the Upper Hutt District. With the nature and span of the natural hazard in hand two aspects of risk are critical:

i. risk of event, and

ii. value at risk.

Even at this stage it is worth noting the hazards identified vary greatly in their span, expected frequency and impact. A serious rupture of the Wellington fault could prove catastrophic in seconds with many lives lost. The impact of the slow settlement of the Mangaroa peatlands does not put lives at risk. Instead, the impact over time on property could prove large.

These events are distinctly different, yet a framework is needed to assess the benefits of the natural hazard policies put in place to reduce risk and mitigate impacts.

We frame benefits under four key elements: (i) risk to life, (ii) risk to property, (iii) risk to infrastructure networks, and (iv) economic resilience, we describe in Table 12.

Table 12: Description of expected benefits

Benefit	Description
Reduced risk to life (death or injury)	Reducing the probability that individuals are injured or killed because of the natural hazard. This includes event specific hazards, such as structural failure caused by earthquakes or rainfall induced landslides. This also includes non-event related hazards, such as structural failure caused by development on poor ground conditions.
Reduced risk to property	Reducing the probability that property is damaged because of the natural hazard. This includes event specific hazards, such as structural failure caused by earthquakes or rainfall induced landslides. This also includes non-event related hazards, such as structural failure caused by development on poor ground conditions.
Reduced risk to infrastructure networks	Development in a hazard area may be accompanied by development or improvements to infrastructure networks. In the event of damage to infrastructure, there could be system wide effects and implications beyond the immediately affected area. For example, placing electric substations, water treatment/storage, or key telecommunications equipment in a hazardous area.
Economic resilience	The above three benefits will likely improve the resilience of the local economy to natural disasters. The whole of this benefit may be greater than the sum of each of the three benefits above.

Source: Sense Partners

4. Quantifying costs and benefits

4.1. Costs

4.1.1. Increased construction costs

Wellington Fault

New building activities within the Wellington Fault hazard are likely to be heavily restricted given Natural Hazard Policy 4 suggests avoiding the construction of new buildings.

But extensions to existing buildings are restricted discretionary activities. So we should quantify the impacts of the natural hazard policies on these construction activities.

Approximately 298 properties, are currently affected by restrictions arising from being in the fault band. If we compare these properties to similar properties which are close by, but not on the fault band, we can get a sense of any differences in properties that might impact our assessment the costs of alternations. With changes to the identified fault hazard:

- 178 properties will remain within the Wellington Fault Overlay.
- 156 properties will no longer be within the Wellington Fault Overlay.
- 327 properties will be added to the Wellington Fault Overlay.

Table 14 below presents estimates of the differences in land values for properties currently in the fault zone. We estimate values for properties on the current fault band, and properties within approximately 160m of those properties on the fault band.

We use properties near the fault, rather than all properties across Upper Hutt, to try and account for changes in all the other factors that also determine land value. Limiting the analysis to properties close to those on the fault band can account for much of the differences we might expect to see. But Table 13 clearly shows properties have similar characteristics in terms of land and capital values regardless of whether the property lies within or external the current fault hazard.

Table 13: Properties in the fault zone have similar characteristics to nearby properties

	LV:CV	*LV/ha:CV*	*Landval/ha*	*Landval*	*Capval*
Near fault	0.58	8.9	$ 5,022,543	$ 331,553	$ 588,645
On fault	0.59	8.3	$ 4,829,497	$ 355,100	$ 612,808

Source: Sense Partners

So we can proceed by looking at possible impacts on typical alteration costs across Upper Hutt.

The cost for adding a consent alone and a small addition to costs (we assume 2.5 percent, given the predominance of stand-alone dwellings for which alterations are unlikely to materially alter load resistance or likelihood of collapse) for the impact of the fault zone on alteration costs, increases typical alteration costs by $2,493.35 in 2022 dollars.

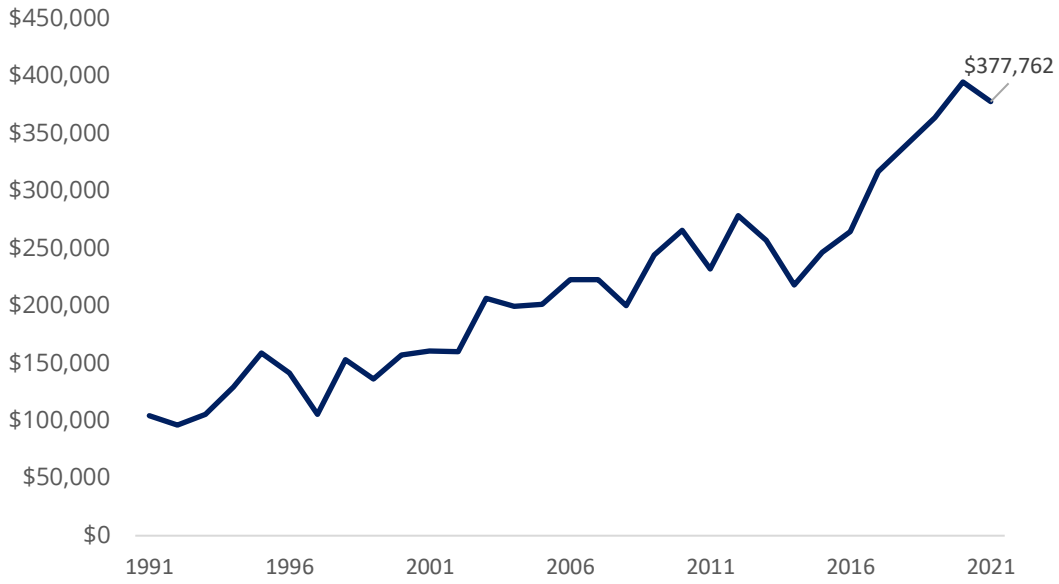
Based on the size of Upper Hutt's existing housing stock and building consents issued for alterations over the last 2 years, each year, the average property has a 1.5 percent of undergoing a renovation that requires a consent. This suggest only a small number of additional properties within the fault zone are typically renovated (about 15 properties every two years) for expected additional costs of $18,887 for alteration costs in the fault zone.

The annual costs of increased costs of construction are likely to be small for the properties impacted by the Wellington fault zone since these activities are largely precluded in the affected areas.

Mangaroa Peatlands

To cost the impact on new construction, we first need to assess total construction costs for an average property. Consenting activity suggests build costs of nearly $400,000 in 2021

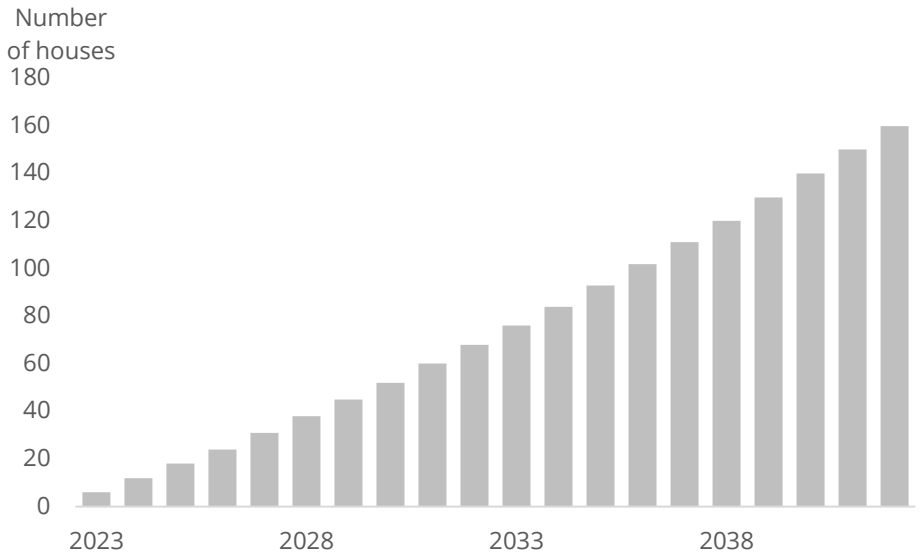
Figure 9: Consenting activity suggests build costs of nearly $400,000 in 2021



Source: Statistics New Zealand

In terms of volume, the Housing and Business Assessment 2019 identified potential capacity for Mangaroa at between 243-274 additional dwellings over the period 2017 to 2047. Outcomes are uncertain, but at that time, these dwellings were not considered feasible but provide an indication of possible yield. Figure 10 provides a smoothed representation of the growth implied by the HBA from 2022.

Figure 10: Stylised growth projection for Mangaroa development



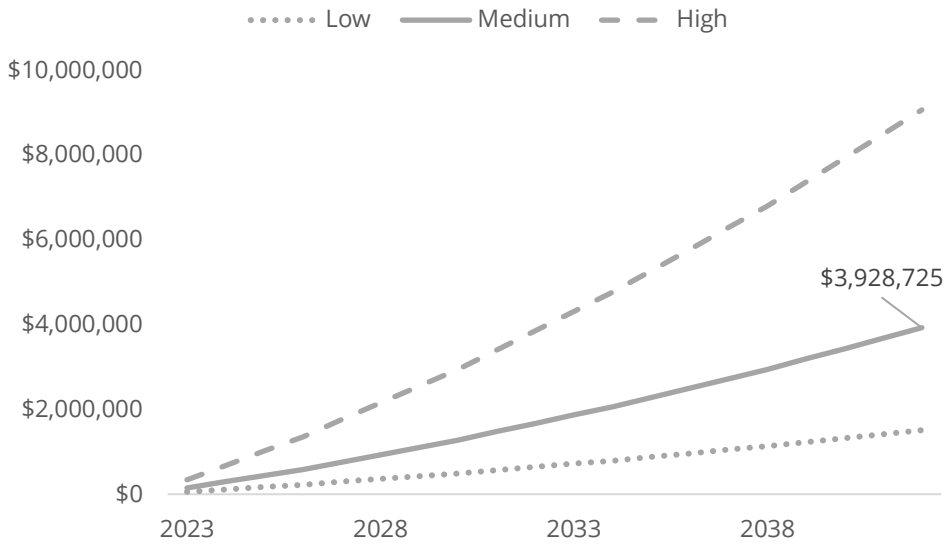
Source: Sense Partners

It is far not clear such a demand profile is likely for Mangaroa. Demand determines development of a parcel of land, whether from Greenfields or intensification.

Demand to live in an area will be influenced by a range of factors. This may include proximity to employment, good schools, transport links, or any other amenity of value to prospective residents. So we view the projection in Figure 10 as an upper bound on possible volumes.

With a view on volumes and likely costs, we can assess the potential impacts of the costs of development for the Mangaroa peatlands. Figure 11 shows these costs.

Figure 11: Stylised potential developments costs for development at Mangaroa
Cumulative additional costs for development at Mangaroa, under new natural hazard policies



Source: Sense Partners

Under the low scenario (2.5 percent additional costs), total costs are a little more than $5 million in 2022 dollars by 2047. The medium scenario (6.5 percent extra costs) suggests extra costs of about $5.2 million dollars by 2047. The high scenario, where constructions costs are 15 percent higher, hits $12 million by the end of the period.

It is important to recognise what these costs represent. These costs are induced by the Natural Hazard policies with the expectation that the requirements reduce risk and mitigate costs from remediation at a future date.

Private builders could of course, opt to proceed with many of the recommended construction techniques under the "do nothing" scenario. This would reduce both the size of additional costs and the size of additional benefits. If this was the case, the low scenario is perhaps more representative of the wedge between the Natural Hazard policy and private behaviour.

But at the upper end, Figure 11 suggests the potential of non-trivial impacts on construction costs in the Mangaroa peatlands.

High slope hazard

Although the high slope hazard is sizable, in practice the hazard describes areas that are unlikely to see large scale development. The additional costs from high slopes require these sites to be at a substantial demand premium for construction to be warranted.

Usefully, the Housing and Business Assessment 2019 sets out the expected development profile to 2047 across key areas within Upper Hutt (see Table 14). That table shows that the lion's share of development is expected within Trentham, the CBD, and the Urban South.

Table 14: Projected housing by type and area within Upper Hutt

Area	Apartments	Terraced	Standalone	Greenfields	Total	%	High slope
Urban South		78	226	1,116	1,420	0.5%	7
Trentham/ Riverstone		93	276	544	913	0.5%	5
Upper Hutt CBD	9	39	291	369	708	0.0%	0
Urban North				222	222	2.0%	4
Akatarawa/ Moonshine				567	567	2.5%	14
Mangaroa/ Whitemans					0		
Total	9	210	793	2,818	3,830		30

These areas do not contain large areas of high-sloped land that could be expected to provide a large amount of housing. Instead, other more efficient sites from a construction perspective are likely to be built out first.

We assess the likelihood of building on a high-slope site within each area that we show in the penultimate column of the table. Outcomes are uncertain, but our assessment suggests only about 30 dwellings are likely to be built in high-sloped areas.

Additional costs from the policy include geotechnical fees that are about $2,500 in 2022. Based on these costs, expect an additional $150,000 of costs from the high slope hazard policies.

4.1.2. Foregone Development

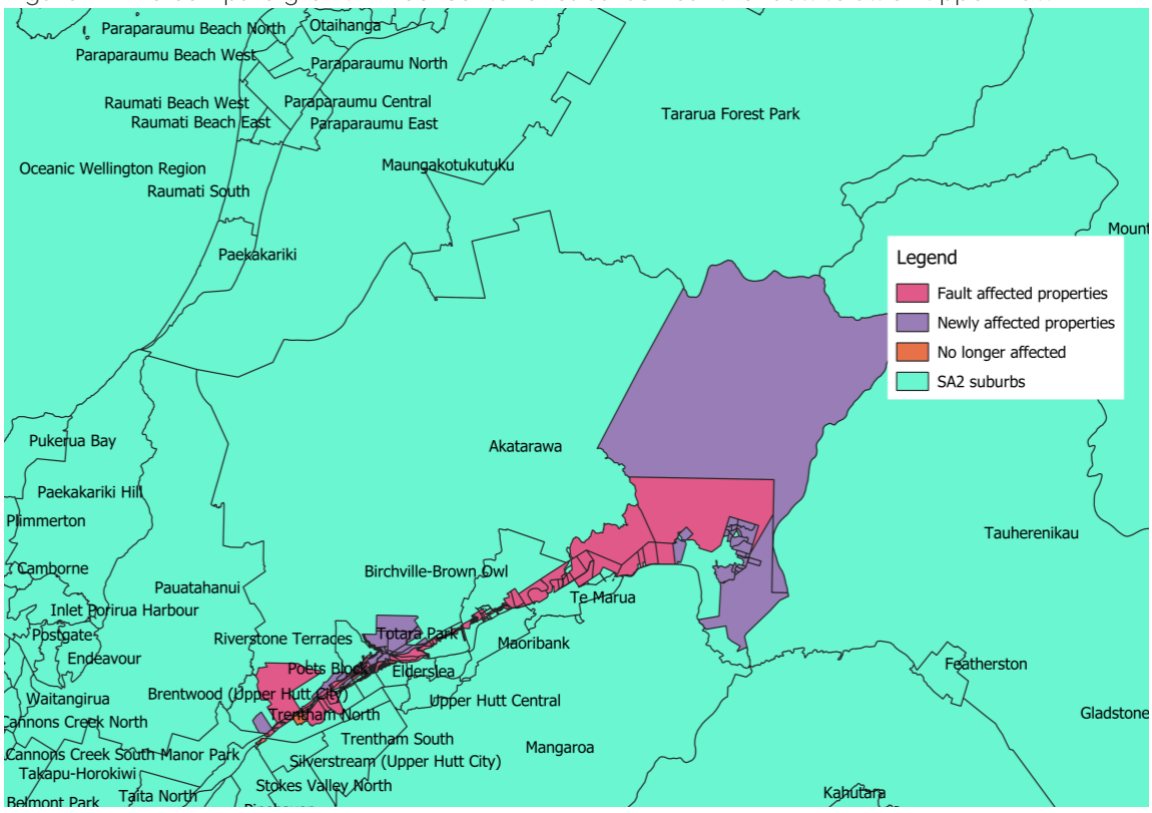
Wellington Fault

We examine foregone development across the three sites. On the margin, increased costs at each site will reduce the likelihood of development.

But we need to tread carefully. Counting both the increase in construction costs *and* any reduction in development amounts to double counting of costs.

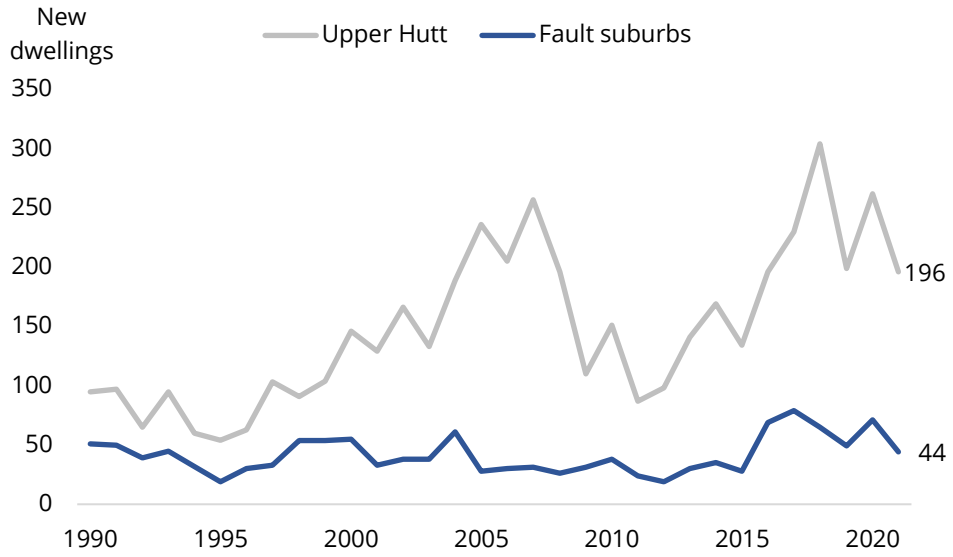
To size likely impacts on construction, we look at the difference in growth rates of consents for properties in suburbs near the fault affected regions (Birchville-Brown Owl, Brentwood, Ebdentown, Elderslea, Poets' Block, Silverstream and Totara Park, see Figure 12) compared to the rest of Upper Hutt

Figure 12: We compare growth in consents for suburbs near the fault to all of Upper Hutt



Source: Sense Partners

Figure 13: Without constraint, we expect modest growth in suburbs near the fault



Source: Sense Partners, Statistics New Zealand

Mangaroa peatlands is the most obvious site where foregone development might be possible. The Mangaroa site is not a guaranteed development opportunity even without the increased risk from peat soils. So small but not immaterial changes in the cost of construction could swing development from a viable proposition to an unlikely option.

4.1.3. Underutilised infrastructure

The Natural Hazard policies are likely to lead to a modest reshaping of where people live across Upper Hutt. The size of the existing housing stock (just under 16,000 occupied dwellings in the 2018 census) suggests changes on the utilisation of infrastructure are likely to be small.

The Mangaroa peatland has some infrastructure that could have higher utilisation rates but equally, additional development would require new infrastructure within the area. So we set costs of underutilisation of infrastructure to zero for the Natural Hazards policies.

4.2. Benefits

4.2.1. Wellington fault

A rupture of the Wellington Fault likely represents a substantial risk to life, property, and infrastructure networks in not just Upper Hutt, but the broader Wellington region.

Earthquake risk is difficult to assess:[4]

> "...the frequency, severity and consequences of earthquake events are highly unpredictable. And the point at which a specified building will collapse is acknowledged (in NZS 1170 (the structural design standards, and by the engineering profession) as being difficult or impossible to accurately assess because it depends on a number of variables." (MBIE 2016)

Understanding if a building will fall down and kill or injury occupants is critical but difficult to assess. Recent research by Rhoades et al 2011 suggests the risk if a rupture is relatively high:

> "The estimated probability of rupture of the Wellington-Hutt Valley segment of the Wellington Fault in the next 100 years is about 11% (with sensitivity results ranging from 4% to 15%), and the probability of rupture in the next 50 years is about half of that, about 5%." – Rhoades et al. 2011

We also note that the recurrence internal range for the Wellington fault is suggested to be at the low end of earthquakes within the Region (see Table 15), at less than once every 2,000 years.[5]

Table 15: Recurrence interval for the Wellington Fault

Fault name	Recurrence interval class	Recurrence interval range	Confidence of interval classification
Wellington fault	I	≤2,000 years	High
Ohariu fault	II	>2,000 years to ≤3,600 years	Medium-low
Aotea fault	III	>3,500 years to ≤5,000 years	Medium
Shepherd's Gully fault	III	>3,500 years to ≤5,000 years	Low
Evans Bay fault	IV	>5,000 years to ≤10,000 years	Medium
Moonshine fault	IV	>5,000 years to ≤10,000 years	Low
Terawhiti fault	IV	>5,000 years to ≤10,000 years	Low

[4] A risk-based approach is critical – see Crawford et al. 2018 and Godschalk et al. 2009.
[5] See Morgenstern and van Dissen 2021.

To make progress, we use the Rhoades et al. 2011 measure of the probability of a rupture. We combine the probability of rupture with the costs suggested by summarise the expected cost of a rupture of the Wellington fault suggested by Saunders et al. 2013, that we show in Table 16. Then we test the impact of the policy in mitigating likely impacts.

Table 16: Framing the costs of an earthquake event

Severity of impact	Insignificant (I)	Minor (II)	Moderate (III)	Major (IV)	Catastrophe (V)
Social/ Cultural	No buildings of social/cultural significance within hazard zone have functionality compromised	1-5% of buildings of social/cultural significance within hazard zone have functionality compromised	6-10% of buildings of social/cultural within hazard zone have functionality compromised	11-24% of buildings of social/cultural significance within zone have functionality compromised	≥25% of buildings of social/cultural significance within hazard zone have functionality compromised
Buildings	<1% of buildings within hazard zone have functionality compromised	2-10% of buildings within hazard zone have functionality compromised	11-20% of buildings within hazard zone have functionality compromised	21-49% of buildings within hazard zone have functionality compromised	≥50% of buildings within hazard zone have functionality compromised
Critical buildings	No damage within hazard zone, fully functional	1-5% of buildings within hazard zone have functionality compromised	6-10% of buildings within hazard zone have functionality compromised	11-24% of buildings within hazard zone have functionality compromised	≥25% of critical facilities within hazard zone have functionality compromised
Lifelines	Out of service for up to 2 hours (affect ≥20% of population)	Out of service for 2 hours to 1 day (affect ≥20% of population)	Out of service for 1 day to 1 week (affect ≥20% of population)	Out of service for 1 week to 1 month (affect ≥20% of population)	Out of service for >1 month (affect ≥20% of population)
Economics	<0.01% of regional GDP	0.01-0.1% of regional GDP1	0.1-1% of regional GDP	1-10% of regional GDP	>10% of regional GDP
Health & safety	No dead or injured	≤1 dead and/or 1-10 injured	2-10 dead, and/or 11-100 injured	11-100 dead, and/or 101-1,000 injured	>101 dead and/or >1,000 injured

Source: Saunders et al. 2013

Impacts

Impacts of a fault rupture are uncertain but are generally likely to be very large. In the event of a fault rupture, averaging across the moderate and major scenario in the table suggests the deaths of 50 people and about 500 injuries. Treasury's CBAx model has a statistical value of life of $4,932,486. The cost of a serious road injury is $593,304. These numbers suggest a health and safety impact of $543 million dollars in 2022 dollars.

The table suggests immediate economic impacts are about 5 percent of local GDP from a moderate to major event. Infometrics reports Upper Hutt GDP as $2,170 million the year to December 2021 (2021 prices). So the economic impact could be about $108 million.

Lifelines would likely be severely impacted, particularly given the narrow transport links into and out of the region. Given the challenge of quantifying these impacts, qualitatively, these impacts present upside to our baseline numbers.

The largest costs are likely to relate to rebuilding. Costs for the Christchurch earthquake were $40 billion (in 2015 dollars) and we use these as a guide.[6] First, we adjust for inflation (so $46 billion in 2022 dollars) and the size of the cities that suggests a ratio of about 0.125 reflecting the relative size of the housing stock.

On this basis a medium to moderate earthquake, like the Christchurch earthquakes, could cause about $2.3 billion in damage to the residential stock and about $700 million to infrastructure with the remainder commercial property.

Richer analysis, perhaps using a Building Importance Category (BIC), would be needed. In addition, a site-by-site analysis could identify properties of social and cultural significance at risk.

But these numbers provide a basis to test the impact of the policies that relate to the fault zone. The Christchurch experience suggests$137,307 of damage to the average residential property.

Given the fault zone identifies properties most at risk, we assume costs of $150,000 per property.

While these costs are high, the likelihood of an earthquake and the impact of the policy relative to the baseline must be accounted for. The fault zone applies across a small number of properties.

In terms of health and safety, we estimate that about 50 people would have lived in the 20 properties that we estimate are precluded from development by the fault zone. We think it is reasonable that the policy might prevent 2 deaths and 10 people from serious injury in the event of an earthquake.

Similarly, we discount economic impacts by the probability of an earthquake using an 11 percent probability of an event in the next 100 years. We also consider the spatial impact of the policy is small relative to the broad Upper Hutt region. This suggests the following discounted costs of an earthquake, ameliorated by the natural hazard policies:

- Health and safety - $2,1118,141
- Economics - $255,483
- Buildings - $2,114,731

[6] See Wood et al. 2016.

4.2.2. Mangaroa Peatlands

Remediating properties after land settlement can be costly. Impacts are uncertain and will span a range of outcomes. Our reading of likely costs suggests an expected impact of about $35,000 in 2022 dollars that we apply to properties that we assume are built without the types of construction methods the policies would proscribe. These include for reinforced soil-cement rafts and other construction techniques that may develop over time to address land settlement.[7]

We then apply these costs to the development profile (160 properties over 20 years) we show in Figure 10. The feasibility of development in Mangaroa remains marginal relative to other locations, despite as-the-crow-flies proximity to the CBD in Upper Hutt. It is difficult to forecast with precision development outcomes. But we work with the likelihood (on both the cost and benefit side) that our development profile is 50 percent likely.

This suggests potentially substantial benefits from the policies directed at the Mangaora Peatlands of about $13 million. This is a function of the relatively large potential development profile compared to both the Wellington fault hazard and the high slope hazard.

4.2.3. High slope hazard

Landslide hazards are likely to be mitigated by limiting new builds to appropriate sites and robust build platforms. Sites may also have to be setback from high-slope areas.

Our profile for development of the high-slope areas rests a propensity applied to the Housing and Business Assessment on a suburb-by-suburb basis. There are uncertainties, but this method suggests 30 new builds over the next twenty years in these high-slope areas.

In the absence of the natural hazards policies, private developers are likely to adopt constructing practices that are robust and appropriate to local hazards, but not always. As a guide we assume that over the twenty-year period we focus on, in the absence of the policies one of the new builds will be subject to a landslide that requires a full rebuild of the property. We do not add impacts on neighbouring properties. This implies benefits of $393,087 – our estimate of the likely rebuild cost in 2022 dollars.

[7] See Beaumont 2021 and EQC: https://www.eqc.govt.nz/assets/Publications-Resources/What-are-reinforced-soil-cement-rafts-Factsheet.pdf. Mahmod et al. 2016 and Pelsma et al. 2020 show lessons from an international perspective.

5. Summary

We present the summary of the cost-benefit analysis in Table 17. We use a 5% real discount rate to present all figures from 2023-2042 in 2022 dollars. Our analysis shows each policy represents value for money: likely benefits exceed costs returning a benefit-cost ratio of 2.73.

Table 17: Our summary shows benefits likely exceed costs for the suite of policies

Item	Value
Costs	
Wellington Fault	
- Increased construction costs	$227,931
- Foregone development	$2,226,033
Subtotal	$2,453,964
Mangaroa Peatlands	
- Increased construction costs	$1,964,362
- Foregone development	$2,114,731
Subtotal	$4,079,094
Slope Area	
- Increased construction costs	$150,000
- Foregone development	nil
Subtotal	$150,000
Under-utilised infrastructure	nil
Total Costs	**$6,683,058**
Benefits	
Wellington Fault	
- Health and safety	$2,118,141
- Economics	$255,483
- Buildings	$2,114,731
Mangaroa Peatlands	$13,337,684
High-slope Hazard	$393,087
Total Benefits	**$18,219,128**
Benefits – Costs	**$11,536,070**
Benefit/Cost Ratio (BCR)	**2.73**

References

Beaumont, L, 2021, "Settlement Performance of Dwellings Constructed on Takanini Peats", NZGS Symposium, https://www.nzgs.org/library/settlement-performance-of-dwellings-constructed-on-takanini-peats/

Coffey Services 2020, "Upper Hutt City Council: Residential & Rural Chapter Review – Natural Hazard Review 773-WLGGE225406AB, 6 March 2020

Crawford, M. H., Crowley, K., Potter, S. H., Saunders, W. S. A., & Johnston, D. M. 2018. Risk modelling as a tool to support natural hazard risk management in New Zealand local government. *International Journal of Disaster Risk Reduction*, *28*, 610–619.

Godschalk, D. R., Rose, A., Mittler, E., Porter, K., & West, C. T. 2009. Estimating the value of foresight: Aggregate analysis of natural hazard mitigation benefits and costs. *Journal of Environmental Planning and Management*, *52*(6), 739–756

Greater Wellington Regional Council, 1996, Sheet 3 Hutt Valley (1st ed.) Combined Earthquake Hazard Map 1:30000, Pub. No. WRC/RP-T-96/14 Greater Wellington Regional Council, Wellington, New Zealand.

Mahmod, Ali Abdul-Wadoud, Sabarudin Mohd, Mohd Idrus Mohd Masirin, Saiful Azhar Ahmad Tajudin, Ismail Bakar, Adnan Zainorabidin, Azrul Zulwali Kifli, and Ling Jen Hua, 2016 "Construction of Buildings on Peat: Case Studies and Lessons learned", MATEC We of Conferences 47, https://www.matec-conferences.org/articles/matecconf/pdf/2016/10/matecconf_iconcees2016_03013.pdf

MBIE 2016, "Regulatory impact statement: Regulations under the Building (Earthquake-prone Buildings) Amendment Act 2016", https://www.mbie.govt.nz/assets/ed8979625b/ris-regulations-under-the-building-amendment-act-16.pdf

Morgenstern, R and R J van Dissen 2021, "Active fault mapping and fault avoidance zones for Wellington City", Lower Hutt, GNS Science, Consultancy report 2020/57

Pelsma, Tim A. H. M., Anne Marieke Motelica-Wagenaar and Simon Troost 2020, "A social costs and benefits analysis of peat soil-subsidence towards 2100 in 4 scenarios", Proc. IAHS, 382, 669–675, 2020https://doi.org/10.5194/piahs-382-669

Rhoades, D., Van Dissen, R., Langridge, R., Little, T., Ninis, D., Smith, E., & Robinson, R. 2011. "Re-evaluation of conditional probability of rupture of the Wellington-Hutt Valley segment of the Wellington Fault". *Bulletin of the New Zealand Society for Earthquake Engineering*, 44(2), 77–86. https://doi.org/10.5459/bnzsee.44.2.77-86

Saunders, W S A, J G Beban, and M Kilvington, 2013, "Risk-based land use planning for natural hazard reduction, GNS Science Miscellaneous Series 67, September.

Sense Partners 2019, "Cost Benefit Analysis of accommodating growth with existing policies,", report for Upper Hutt City Council, December.

Wellington councils 2019, Wellington Regional Housing and Business Development Capacity Assessment, Chapter 6 Upper Hutt, https://planningforgrowth.wellington.govt.nz/__data/assets/pdf_file/0019/3286/Wellington-Regional-HBA-Chpt-6-Upper-Hutt-City-Council.pdf

Wood, Amy, Ilan Noy and Miles Parker 2016, "The Canterbury rebuild five years on from the Christchurch earthquake", *Reserve Bank of New Zealand Bulletin*, February

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