Ministry for Primary Industries

Benefits and Costs of the Wilding Pine Management Programme Phase 2

s 9(2)(a)

November 2018

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Contents

Glossary .... **vii**

Executive summary ....

ix

1. Introduction **1**

1.1 Context 1
1.2 Cost benefit analysis 1
1.2.1 Limitations 2
1.3 Control options 3
1.3.1 Control options by hectares 4
1.3.2 Explaining the Do Nothing scenario ("losing the war") ....
5 1.3.3 Without control, wilding conifers will spread into New Zealand's most sensitive landscapes… 6
1.3.4 … and productive land will be lost 6

2. The benefits of controlling wilding pines outweigh the costs **7**

2.1 An intergenerational investment in natural capital 7
2.1.1 Net benefit 8
2.1.2 Ratios tail off for intermediate scenario due to prioritisation 8
2.1.3 Wellbeing 8
2.1.4 Intergenerational impacts 9
2.2 Water impacts dominate the results 10

3. Achieving control **11**

3.1 What happens when a site is controlled 11
3.1.1 The methods of controlling wilding conifers 12
3.1.2 Determinants of control costs per hectare 13
3.1.3 Controlling trees of different densities 13
3.2 What happens when a site isn't controlled 14
3.2.1 Some land is more vulnerable than others 15

4. Programme costs **18**

4.1 Government investment 18
4.2 Non-fiscal costs 18
4.2.1 External contributions 18
4.2.2 Deadweight loss of taxation 19
4.2.3 Social, cultural and other costs and risks of control activities 19

5. Control protects productivity **21**

5.1 Invasion of conifers reduces the productive potential of land 21
5.2 Future analysis may capture additional land types 21
5.3 Large tracts of land will be controlled and protected, and some will

be surrendered 22
5.4 Productivity impacts rely on assumptions about wilding growth and spread 24
5.5 How productive land is impacted varies by type 25
5.5.1 Low value or depleted grass land 25
5.5.2 Arable land 26
5.5.3 Horticultural land 26
5.5.4 Sheep and beef land 27

6. Control protects water 28
6.1 A significant impact on water yield 28
6.2 Wilding conifer control protects water for irrigation 29
6.2.1 Analysis only includes catchments experiencing very high water stress 29
6.2.2 Treating wildings around Canterbury and Hawke's Bay saves around 8 percent of the value of irrigation water in those districts 30
6.3 Wilding conifer control protects water yield for hydroelectricity generation 30
6.3.1 Catchment-based analysis of hydro impacts 31

7. Operational impacts of Phase 2 34
7.1 A variety of roles will need to be filled 35
7.1.1 The project management workforce 35
7.1.2 The contractor workforce 35
7.1.3 Volunteer Workforce 36
7.1.4 Sourcing skilled workers will be a focus 36

8. Other impacts of control activity 37
8.1 Control will protect biodiversity and landscape values 37
8.1.1 The impact 38
8.1.2 We have applied a conservative valuation of biodiversity 38
8.1.3 Stepping behind the values in previous studies 38
8.2 Control will protect social and cultural values, but the extent of these values is unknown 40
8.3 Wilding conifer control reduces fire control costs 41
8.3.1 The impacts 42
8.4 Control may have no negative impact on carbon (so no values have been included) 43

9. Conclusion 44

10. References 45

Appendices

Appendix 1 Methodology notes 51

Appendix 2 Data tables 55

Tables

Table 1 Control options 4

Table 2 Costs, benefits and ratios of marginal cost to marginal benefit ($NZ, present value) 8

Table 3 Control, by density class 14

Table 4 Productivity loss generic assumptions 24

Table 5 Illustration of variation in PVs - Low Value Grassland PV assumptions according to density class 26

Table 6 Impact of control on irrigation water, NPV 50 years 29

Table 7 Present value impacts on hydroelectricity resource rents, per hectare of high grassland controlled, protected or surrendered, by catchment. 33

Table 8 NPV avoided fire prevention costs (50 year projection) 42

Figures

Figure 1 Control options for Phase 2 of the Wilding Conifer Control Programme 4

Figure 2 Summary of results against Living Standards Framework 9

Figure 3 Control at Flockhill Station, Craigieburn (used with permission) 12

Figure 4 Average age of significant coning 14

Figure 5 Mt Dewar spread of wilding conifers (1954-2004) 15

Figure 6 Vulnerability 17

Figure 7 Direct fiscal cost of Phase 2 of the Wilding Conifer Control Programme 18

Figure 8 Non-fiscal costs 18
Figure 9 Productive land controlled, protected and surrendered in the Intermediate scenario 23
Figure 10 High water stress areas (highest stress shown in red) 30
Figure 11 Wilding conifer spread into hydro-generation catchments 32
Figure 12 Operational impacts 34
Figure 13 Hydroelectricity generation statistics 52
Figure 14 Current infestation of wilding conifers (productive land highlighted grey) 55
Figure 15 Controlled Management Areas, by scenario (shading indicates control) 56
Figure 16 Controlled wilding conifers, by scenario 59

Glossary

CBA	Cost Benefit Analysis
Density classes	Dense: >75% overall cover; >600 stems per hectare; stems spaced <4m apart Intermediate: 15>1% overall cover; 125>8 stems per hectare; stems spaced 9<35m apart Scattered: >1% overall cover; <8 stems per hectare; stems spaced >35m apart Outlier: 75 >15% overall cover; 600>125 stems per hectare; stems spaced 4<9m apart
MPI or the Ministry	The Ministry for Primary Industries
NPV	Net Present Value
Phase 1	Phase 1 of the National Wilding Conifer Control Programme
Phase 2	Phase 2 of the National Wilding Conifer Control Programme
Significantly vulnerable land	Rated as Very High, High or Moderate vulnerability according to the Wilding Conifer Control Programme's vulnerability classification

Executive summary

Wilding Conifer Control Programme CBA of Phase 2 – December 2018

Wilding conifers are a serious pest

- Wilding conifers are a serious and pressing established pest in New Zealand. They reduce the productivity of primary industries and damage the environmental values that New Zealand is renowned for.

Context

- The Government has been running a national programme to control wilding conifers since 2016.
- The Wilding Conifer Management Programme is run by the Ministry for Primary Industries.
- Since 2016 the Ministry has been leading and coordinating stakeholders around the country, understanding the profile of infestation and future vulnerability and planning for a wider roll-out of control efforts.
- The first phase harnessed the funding support and commitment of wilding tree management groups, land holders, and central and local government.
- The first phase treated wilding conifers across approximately 1.5 million hectares of New Zealand's high country.
- MPI is seeking to extend this work into further phases. Phase 2 of the Programme – the subject of this cost-benefit analysis – involves increasing control to roll back the area occupied by wilding conifers to the point where they can be sustainably managed by landowners.

The aim is to achieve sustainable management

- A national Wilding Conifer Control Programme in Phase 2 aims to fight wilding conifer spread by:
  - coordinating efforts and harnessing skills across multiple agencies in central and local government alongside other stakeholders
  - developing and maintaining information systems to monitor infestations and areas at risk from invasion, and to support control planning
  - improving prevention through raising community awareness and promoting best practice in the planting of conifers.

Approach

- This cost-benefit analysis (CBA) takes data about the extent and location of wilding pines and predicts the consequences of leaving wilding pines to spread uncontrolled versus the proposed programme of treating and clearing wilding conifers.
- Clearing wilding conifers ("CONTROL") will restore the land and protect surrounding areas from invasion ("PROTECT"). Surrendering to wilding spread ("SURRENDER") will destroy the value of the land and make surrounding areas vulnerable to invasion.
- Three strategies are costed: Doing Nothing, Minimum Plus ("Treading Water") and Intermediate ("Turning the Tide").
  - Doing Nothing – some control is achieved at a local level at first, but this is not sufficient to achieve protection in the long term and vast tracts of vulnerable land are surrendered to wilding conifers. 7.5 million hectares are lost.
  - Minimum Plus ("Treading Water") – a national programme is run with a slightly broader scope than Phase 1, achieving control over 3 million hectares. Over the long term, 3 million hectares are protected but 4.5 million hectares are surrendered.
  - Intermediate ("Turning the Tide") – a national programme is run with a wide scope (but not across all of New Zealand's wilding-affected areas). Control efforts are scaled up to achieve nationwide containment and eradication, focussing control across the most vulnerable landscapes. The programme controls 1.8 million hectares, almost all of New Zealand's current infestation. The programme is effective at sustaining control into the long term, and 7.25 million hectares are protected. A small amount, 0.25 million hectares, is surrendered.
- To illustrate the long term consequences of surrendering land to wilding conifer invasion, annualised impacts of surrender are examined over a 50 year time horizon, then discounted to present day values.

The benefits of control and protection are clear and greatly outweigh the costs

- Both intervention options (Minimum Plus and Intermediate) have a demonstrably higher benefit return than costs.
- Doing nothing, or doing little, generates a large negative impact: a loss of $4.6 billion. Without national intervention wilding pines will then spread to 7.5 million ha of vulnerable land. This could take as little as 15 to 30 years.
- The consequences of doing nothing to stop this spread are profound. For example the 7.5 million hectares of surrendered land by year 50 in the Do Nothing scenario includes 537,000 hectares of productive land, which is worth $739 million of productive potential. In addition, the surrender affects water with productive potential of $2.9 billion (consisting of $1.95 billion of irrigation impacts and $955 million of hydro

impacts).The biodiversity loss will include New Zealand's most sensitive landscapes and water catchments.

- Not only will doing nothing fail to achieve the objective of sustainable management, it will result in substantial cost for the country. It can be as little as $5–$10 per hectare to treat sparse infestations however control costs escalate over time. And treating dense infestations will typically cost $2,000 per hectare to aerial boom spray.
- The CBA demonstrates that the Intermediate option for Phase 2 is sufficient to markedly roll back the area occupied by wilding conifers and 'turn the tide'. It will achieve a net benefit of $6.1 billion (net present value), a benefit ratio of 38:1.
- The Minimum Plus scenario will achieve control but will have a smaller net benefit, because it achieves less control and protection in the near term. The net benefit of this option is $2.6 billion (net present value).

Biodiversity valuation is highly conservative

- Biodiversity values are significant but in this CBA they are conservatively quantified. The quantified value on biodiversity does not adequately capture the values protected. For example scaling up to the Intermediate scenario will mean that there are large areas of dense infestation that will be treated early, such as in Wakatipu, the Mackenzie region and near Twizel. Waiting to control these areas (as the Programme would have to in the Minimum Plus scenario) would mean that these trees would cone and spread, not only affecting the flora and fauna in these sensitive landscapes but also making the treatment problem more difficult and costly in the future.
- About three quarters of New Zealand's 70 identified "naturally rare landscapes" are potentially threatened by invasion from wilding conifers, including a zone above the current tree line. These include such highly valued areas as: alpine herb fields, dry tussock lands, geothermal areas and the volcanic plateau, the South Island mineral belt, Coromandel scrub lands, coastal dunes, frost flats and seasonal wetlands.

Weed trees are not valuable under the ETS

- New Zealand's commitments under the United Nations Framework Convention on Climate Change and the Paris Agreement include targets to reduce greenhouse gas emissions by 5% below 1990 levels by 2020 (the 2020 target) and 30% below 2005 levels by 2030 (the 2030 target).The Emissions Trading Scheme (ETS) is New Zealand's key policy tool for reducing emissions and meeting our emission reduction targets.
- The ETS and international agreements determine whether any liabilities arise from clearance of major infestations of wilding pines.
- Wilding forests are ineligible to be registered as post-1989 forests in the ETS, so new wilding conifer forests have no value.
- Allowing the spread of wilding conifer forests is incompatible with the Government's strategies and tools for protecting and conserving biodiversity. Allowing their spread

onto private land is incompatible with allowing other beneficial land uses (such as plantation forests) that do operate as carbon sinks.

- If established before 1990, deforestation liabilities can be avoided when a tree weed exemption has been granted. Deforestation liabilities from wilding clearance can arise when dense infestations are removed and the land is used for a different activity e.g. grazing land. Removing wildings before they become forests avoids such liabilities.
- Where grazing land features trees, but is being managed as grassland, this land would normally be classed as grassland. Consequently any clearance shouldn't incur deforestation liabilities.
- Any potential liabilities arising from deforestation (i.e. removing Wilding Forests) will be minimised through the Programme's Control Plans and post-control land-use remediation.
- Because any liability is small, and will be managed through remediation activities, we have not included a carbon cost in the CBA.

Ongoing investment will be required

- The Intermediate option is sufficient to turn the tide, but not sufficient on its own to win the war. To achieve sustainable management will require ongoing investment beyond four years and into further phases. A wider area will need to be treated, to avoid cross-infestation of already controlled sites.
- MPI expects that up to five control phases will be needed, with costs tailing off as a greater degree of control is achieved.
- This CBA does not account for the control phases beyond Phase 2.

An intergenerational investment in natural capital

- Most of the benefits of Phase 2 will be realised beyond the four years this Phase will run.
- The CBA analysis demonstrates the value of a 'stitch in time'—what is done now has large impacts on natural capital in the future. If the objective is to reach a point where wilding conifers can be sustainably managed using a combination of private landowner action and government support, it is better to act swiftly and decisively now.
- The CBA analysis shows that the Intermediate scenario offers a higher overall net benefit. Each additional hectare of land treated in the Intermediate scenario offers a positive return, with benefits higher than the costs.

Wellbeing

- Many Living Standard Framework domains are affected by wilding conifer removal activities, but the major impacts are on income and consumption and the environment.

These domains underpin New Zealand's Natural Capital, Financial/Physical Capital and, to a lesser extent, Social Capital.

- Income and consumption (Quantified)
- Environment (Quantified)
- Jobs and earnings (Quantified)
- Time use, health and cultural identity (Unquantified)

Results

- The results shown below are of impacts over the long term, 50 years. They show the impact of reducing the area of wilding conifers, sustaining the reduced area into the future and protecting surrounding areas. They also show the impacts of surrendering land to wilding conifers.
- Over the fifty year projection, the CBA results show a ratio of quantified benefit to quantified cost of 60.1 for the Intermediate scenario. Doing nothing has a catastrophic impact on vulnerable land and this is reflected in the negative impact figure.

Costs, benefits and ratios of marginal cost to marginal benefit ($NZ, present value)

	Do Nothing	Minimum Plus	Intermediate
Total quantified benefit of Phase 2	-$5.3 billion	$2.6 billion	$6.3 billion
Total quantifed cost of Phase 2 control	$8 million	$64 million	$166 million
Net benefit	-$5.3 billion (loss)	$2,6 billion	$6,1 billion

Ratio benefit to cost	n/a	42:1	38:1

1. Present value of impact, 2018, discount rate 6% over 50 year projection, $NZ Millions, end-period discounting

The $6.3 billion quantified benefit figure above can be further broken down as follows:

Breakdown of impacts

	Impacts from Intermediate Scenario (Millions)
Land impacts (Income and Consumption)	$ 2,228
Hydro impacts (Income and Consumption)	$ 961
Irrigation impacts (Income and Consumption)	$ 2,006
Sum of Biodiversity impacts (Environment)	$ 429
Sum of Fire impacts (Safety)	$ 654
Sum of Jobs impacts (Jobs and Earnings)	$ 3
Other impacts (Social, Cultural, Health, Time Use)	$ -

Government impacts (Avoided Social Costs)	$ 13
TOTAL BENEFIT	$ 6,295

1. Introduction

1.1 Context

The Government has been running a national programme to control wilding conifers since 2016. The programme's name is the Wilding Conifer Management Programme, run out of the Ministry for Primary Industries.

Since 2016, the Ministry has been leading and coordinating stakeholders around the country, understanding the profile of infestation and future vulnerability and planning for a wider rollout of control efforts. The first phase harnessed the funding support and commitment of wilding tree management groups, land holders, and central and local government.

The first phase treated wilding conifers across around 1.5 million hectares of New Zealand's high country. The cost was $22.5 million, $8 million of which was funded using contributions from Crown agencies, local government, landowners, and trusts.

MPI is seeking to extend this work into further phases. Phase 2 of the Programme – the subject of this cost benefit analysis – involves increasing control to roll back the area occupied by wilding conifers to the point where they can be sustainably managed by landowners. This will include activities aimed at:

- coordinating efforts and harnessing skills across multiple agencies in central and local government alongside other stakeholders.
- developing and maintaining information systems to monitor infestations and areas at risk from invasion, and to support control planning
- improving prevention through raising community awareness and promoting best practice in the planting of conifers.

The aim of the Progamme is to achieve sustainable management: to control wilding conifers and prevent spread.

1.2 Cost benefit analysis

Sapere Research Group has been commissioned to write this cost benefit analysis (CBA) as part of the fiscal bid for funding for Phase 2. The purpose of the CBA is to explore whether the investment in Phase 2 of the Wilding Conifer Control Programme is justified in terms of the economic and societal benefits achieved. This CBA has been prepared in accordance with

Treasury guidance on CBA analysis (including CBAx) and includes brief commentary on how controlling wilding pines aligns with the Treasury's Living Standards Framework (LSF).[1]

This cost benefit analysis (CBA) takes data about the extent and location of wilding pines and predicts the consequences of leaving wilding pines to spread uncontrolled versus the proposed programme of treating and clearing wilding conifers.

Clearing wilding conifers ("CONTROL") will restore the land and protect surrounding areas from invasion ("PROTECT"). Surrendering to wilding spread ("SURRENDER") will destroy the value of the land and make surrounding areas vulnerable to invasion.

Three strategies are costed: Doing Nothing, Minimum Plus ("Treading Water") and Intermediate ("Turning the Tide").

- Doing Nothing – some control is achieved at a local level at first, but this is not sufficient to achieve protection in the long term and vast tracts of vulnerable land are surrendered to wilding conifers. 7.5 million hectares are lost.
- Minimum Plus ("Treading Water") – a national programme is run with a slightly broader scope than Phase 1, achieving control over 3 million hectares. Over the long term, 3 million hectares are protected but 4.5 million hectares are surrendered.
- Intermediate ("Turning the Tide") – a national programme is run with a wide scope (but not across all of New Zealand's wilding-affected areas). Control efforts are scaled up to achieve nationwide containment and eradication, focussing control across the most vulnerable landscapes. The programme controls 1.5 million hectares, almost all of New Zealand's current infestation. The programme is effective at sustaining control into the long term, and 7.25 million hectares are protected. A small amount, 0.25 million hectares is surrendered.

To illustrate the long term consequences of surrendering land to wilding conifer invasion, annualised impacts of surrender are examined over a 50 year time horizon, then discounted to present day values.

1.2.1 Limitations

There are some limitations of the modelling:

- The cost estimate does not include contractors costs associated with Phase 3, Phase 4, and beyond (which will increase the number of hectares covered and invest in spreadreduction activities).
- Consistent with the above, the labour benefit does not include the labour impact associated with contractor employment in future phases.
- The costs shown do not include control in the event that some re-infestation may occur in already controlled areas (that cost is assumed to become part of the budget for landowner operations).

[1] The Treasury. (2018). *The Treasury Approach to the Living Standards Framework*. New Zealand Treasury: Wellington, New Zealand; The Treasury. (2018). *Treasury Guidance: Cost Benefit Analysis Template – Wellbeing domains*. New Zealand Treasury: Wellington, New Zealand.

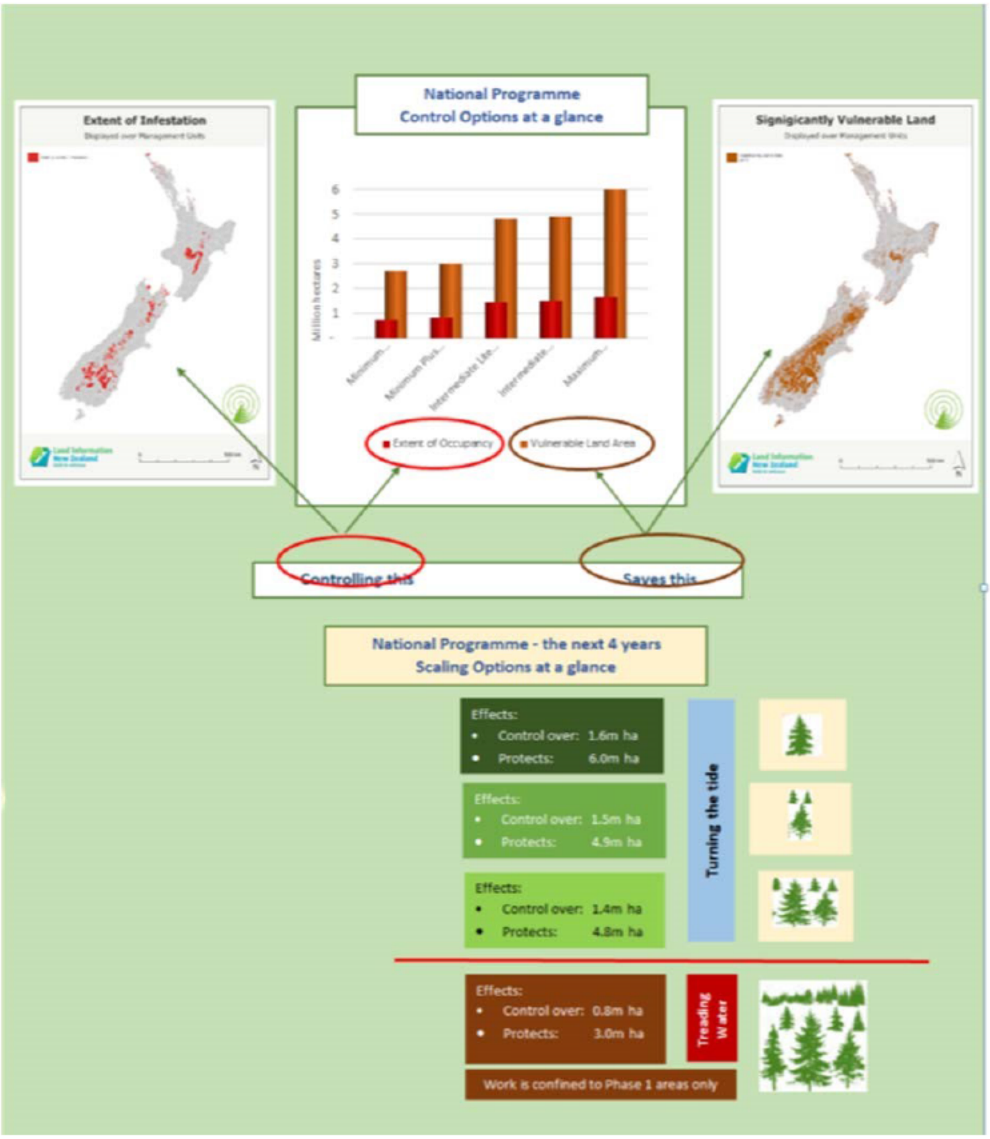
- The quantified amounts do not incorporate valuations of volunteer time or impacts on health and safety.
- Not all potential land use types have been included.

- The impact on cultural values is unquantified (and we explain why in section 8.2).
- The biodiversity valuation is conservative (and we explain why in section 8).

1.3 Control options

The calculation is driven by a list of management areas (including Phase 1 sites) considered to be controlled during Phase 2 of the Programme. Which sites are controlled varies by scenario. The control options for Phase 2 have been developed by MPI. Figure 1 summarises the control options in a visual.

Figure 1 Control options for Phase 2 of the Wilding Conifer Control Programme



Source: Ministry for Primary Industries

1.3.1 Control options by hectares

Table 1 below summarises the modelled control options, in terms of overall hectares protected. The Intermediate scenario controls 96 percent of New Zealand's present wilding conifer infestation; the Minimum Plus Scenario controls 43 percent.

Table 1 Control options

	"Losing the War"	"Treading Water"	"Turning the Tide"

	"Losing the War"	"Treading Water"	"Turning the Tide"
	Status Quo	**Minimum Plus**	**Intermediate**
Government Investment	$0	$44 million	$118 million
Total investment (including by external parties)	$0	$54 million	$140 Million
Controls	Nil	800,000 hectares	1,800,000 hectares
Protects	Nil	3,000,000 hectares	7,250,000 hectares
Surrenders	7.5 million hectares	4,500,000 hectares	250,000 hectares

Source: Ministry for Primary Industries

1.3.2 Explaining the Do Nothing scenario ("losing the war")

If the Wilding Conifer Control Programme was not funded for Phase 2, we might expect the following course of events:

- Funding from volunteer groups and others would continue for a while (perhaps at Phase 1 levels) as councils and others attempt to manage wilding conifers on their own for a year or two. However this would be insufficient to do the follow up control required to lock-in the gains made by the Programme in Phase 1 (except in some very limited areas for the short term).
- Funding would then likely drop to nothing after four years as parties realised the futility of trying to manage wilding conifers without sufficient funds. The situation would return to the pre-programme situation where wilding conifers invade vulnerable land at an exponential rate (until it starts to reach saturation).
- As a consequence there would be 'no control' over any current wilding conifer infestation (at any density or age). Eventually the current infestation might spread into all significantly vulnerable land (nationally: 7,463,418 hectares[2]). This would take a period of 15–30 years. We cannot predict exactly how long this might take or where the spread will happen first, although vulnerability models have been developed to illustrate the highest risk areas.

[2] Note: our do nothing modelling only assumes that wilding conifers densify into their existing footprint, which is currently 1.8 million hectares.

- Some (but not all) types of productive land[3] are vulnerable to invasion. Farmers may try to control this invasion, but on large or remote blocks this may prove to be too costly and onerous. Thus in the 'do nothing' counterfactual scenario, there will be a large amount of 'surrendered' land.
- Surrendered land translates to losses. These include GDP/productivity losses, reductions in water availability (which affects irrigation and electricity generation), greater costs of preventative fire control and impacts on biodiversity, and by extension cultural values attached to our natural environment.

1.3.3 Without control, wilding conifers will spread into New Zealand's most sensitive landscapes…

Throughout New Zealand about 70 naturally rare ecosystems have been identified and about three quarters of these are potentially threatened by invasion from wilding conifers.[4] This threat is explored more in section 8, which explores the biodiversity impacts of wilding conifers.

1.3.4 … and productive land will be lost

In some areas of pastoral farming, wilding conifer infestations adversely impact economic well-being by reducing available grazing land and limiting future land use options due to the high costs of control.

Low producing grassland and depleted grassland, which is highly vulnerable to wilding conifer spread, can be suitable for grazing (as identified by Land Use Capability classification 6 or 7).

2. The benefits of controlling wilding pines outweigh the costs

Our analysis of costs and benefits concludes that the benefits of the control achieved in Phase 2 of the Programme outweigh the costs. A detailed analysis of the costs is included in section 4. Benefits are described in sections 5 to 8.

This section summarises the costs and benefits impacts of Phase 2 against the Treasury's Living Standards Framework. These results are in present value (PV) terms, over 50 years. In calculating all PV figures the discount rate is 6 percent, in line with present Treasury guidance.

The vast majority of benefits of the control activities undertaken during Phase 2 go beyond the four year term. For example, the benefit of removing an outlier tree today is that it is prevented from coning, spreading, and densifying in the future. The analysis estimates the present value associated with removing existing wilding conifer trees. This calculation takes into account the different densities of

[3] The modelling counts the following land uses as productive: high producing exotic grassland, short rotation cropland, orchards, vineyards and other perennial crops, forest-harvested, and depleted or low-producing grassland (only counted if LUC 6 or 7).

[4] s 9(2)(a), Landcare Research, *pers comm*

the trees that will be removed during Phase 2, the productive capacity of the land that these trees inhabit, and the places they may spread to.

A detailed description of the calculations and the assumptions is available in the chapters that follow.

2.1 An intergenerational investment in natural capital

This section summarises the costs and benefit impacts of Phase 2 against the Treasury's Living Standards Framework (LSF). In line with that framework, the analysis highlights the longer term, intergenerational impacts of removing existing wilding conifer trees.

Most of the benefits of Phase 2 will be realised beyond the four years this Phase will run.

The CBA analysis demonstrates the value of a 'stitch in time'—what is done now has large impacts on natural capital in the future. If the objective is to reach a point where wilding conifers can be sustainably managed using a combination of private landowner action and government support, it is better to act swiftly and decisively now.

The CBA analysis shows that the Intermediate scenario offers a higher overall net benefit. Each additional hectare of land treated in the Intermediate scenario offers a positive return, with benefits higher than the costs.

2.1.1 Net benefit

Table 2 Costs, benefits and ratios of marginal cost to marginal benefit ($NZ, present value)

	Do Nothing	Minimum Plus	Intermediate
Total quantified benefit of Phase 2	-$5.3 billion	$2.6 billion	$6.3 billion
Total quantifed cost of Phase 2 control	$8 million	$64 million	$166 million
Net benefit	-$5.3 billion (loss)	$2,6 billion	$6,1 billion

Ratio benefit to cost	n/a	42:1	38:1

2. Present value of impact, 2018, discount rate 6% over 50 year projection, $NZ Millions, end-period discounting

2.1.2 Ratios tail off for intermediate scenario due to prioritisation

A close look at the ratios shows that the ratio for the Minimum Plus scenario (where control is over a smaller area) is more favourable than for Intermediate (where control is scaled-up to achieve nationwide containment and eradication). This is likely because of the prioritisation method followed by the Programme when identifying which sites are priorities for control operations. A ratio that tails off as more area is treated is a good thing: it shows that priorities have been set well. The most valuable (in terms of productivity or landscape, or both) are treated first. There is diminishing marginal value the further down the priority list the Programme goes.

The net benefit of the Intermediate option is significantly higher than the Minimum Plus option, and that is the metric of most importance.

2.1.3 Wellbeing

Many Living Standard Framework domains are affected by wilding conifer removal activities, but the major impacts are on income and consumption and the environment. These domains underpin New Zealand's Natural Capital, Financial/Physical Capital and, to a lesser extent, Social Capital.

- Income and consumption (Quantified)
- Environment (Quantified)
- Jobs and earnings (Quantified)
- Time use, health and cultural identity (Unquantified)

2.1.4 Intergenerational impacts

Figure 2 shows the $6.3 billion quantified benefit figure above in terms of wellbeing impacts. The 50 year results show a clear and sustained net benefit from control activities. This is because in the longer term, the removal of wilding conifer trees will result in a range of tangible and intangible benefits that will enhance intergenerational wellbeing. For example in addition to productivity and water benefits there will be tangible environmental gains in the form of enhanced biodiversity.

Figure 2 Summary of results against Living Standards Framework

	Impacts from Intermediate Scenario (Millions)

Land impacts (Income and Consumption)	$ 2,228
Hydro impacts (Income and Consumption)	$ 961
Irrigation impacts (Income and Consumption)	$ 2,006
Sum of Biodiversity impacts (Environment)	$ 429
Sum of Fire impacts (Safety)	$ 654
Sum of Jobs impacts (Jobs and Earnings)	$ 3
Other impacts (Social, Cultural, Health, Time Use)	$ -
Government impacts (Avoided Social Costs)	$ 13
TOTAL BENEFIT	$ 6,295

2.2 Water impacts dominate the results

The total benefit figure is dominated by the irrigation and hydro-electricity values. This is because wilding conifers will invade the high country grassed areas that feed water into our irrigation rivers.

Given the high value of water and the impact of wilding conifers on water availability during periods of high stress, then the benefit of the Programme is that it provides for control over grassland areas that feed water into irrigation or hydro catchments, particularly if they are 'high water stress regions'. This includes the high land that feeds Canterbury's braided rivers, Otago (Waitaki, Clutha hydro schemes) and Southland (Manapouri hydro scheme). Protecting the flow of water in these areas may have a higher impact than restoring productive land.

The case for government intervention in weed control for protecting water is strong because water is a fugitive resource without clear ownership rights. It therefore suffers from all the classic common resource problems. These problems give rise to the need for public-good programmes to protect the flow and value of water.

3. Achieving control

This chapter describes what it means to achieve control, and what drives the benefits over the long term. It provides a summary of the methodology we used to estimate how the spread of wilding conifers would change under each control scenario.

3.1 What happens when a site is controlled

Control involves spraying, cutting or poisoning wilding conifer trees and doing as much as possible to remove their ability to seed from cones. When a site is controlled, the following impacts happen:

- Wilding conifers will be substantially reduced on extensive or marginal farmland, to levels sustainable for the landowner acting independently.
- There will be requirements for the spread of conifers on to other tenures to be managed by those with conifers on their land (good neighbour rules under the Biosecurity Act 1993).
- Land occupiers will be able to keep open options for other land uses such as pasture or commercial forestry development or other production.
- The area of wilding conifer infestation that needs to be managed by landowners reduces, so the need for government support and subsidy for control activities reduces.

Control does not equate with total eradication. For example there will likely need to be another ten or so years of vigilance on "controlled" blocks by the land occupier to identify seed spread and remove outliers.

Much of the land where wilding conifers spread cannot be used for profitable production, but some of it can be. Figure 14, in Appendix 2, shows that 27 percent of land where wilding conifers are currently located has productive potential (productive land is shaded in grey, and includes high producing exotic grassland, short rotation cropland (or arable land), orchards, vineyards and other perennial crops, forest-harvested, and depleted or low-producing grassland (which we have only counted if LUC 6 or 7). The remaining 73 percent is tall tussock, scrub, indigenous forest or other land uses. These sites have value in other ways but are not used for profit.

When wilding conifers are on a productive site that is controlled, that site can be re-stocked by a farmer and become productive and profitable again. In estimating the benefits of wilding conifer control, this productive but presently invaded land is assumed to be returned to its full potential. But restoring the land takes time. The time it takes depends on whether the infestation had been allowed to become dense, intermediate, scattered or just outliers. Outliers and scattered trees are quick to remove; dense and intermediate trees need time to die and be cleared before the land can be used productively again. Land densely covered with trees will have lost all productivity and will take one to five years to recover (the amount of time it takes depends on the removal technique used and the restocking activities. The most typical recovery time is less than two years). Land covered with scattered and intermediate trees will have suffered a 20-30 percent loss in productivity and may take up to two years to restore to full productivity. Land with outlier trees will have a small impact on productivity, but can be restored almost immediately.

The pictures below show the consequences of growth in conifers and of control. They are of Flockhill Station, Craigieburn: an area controlled during Phase 1 of the Programme.

Figure 3 Control at Flockhill Station, Craigieburn (used with permission)

Craigieburn scene

SH73 - 1970s

Craigieburn scene

SH73 infestation – 2012

Post Control 2018

3.1.1 The methods of controlling wilding conifers

Felling

Felling is a general term for all types of non-herbicidal control. Felling can be via chainsaw, loppers, saw, and hand pulling. If combined with removal, felling has the advantage of making the land beneath the tree immediately available for other uses; felling with removal is usually more expensive than herbicidal applications but may be favoured when aesthetics of dead trees is undesirable. One downside of felling is that when felling opens the canopy there is a high potential for reinvasion.

One upside of this method is that land productivity can be restored quickly. For example, it may only take six months before stock can be reintroduced and 1 to 2 years before maximum stocking rates are achievable.

Aerial basal bark application

Aerial basal bark herbicide application is appropriate for ground-inaccessible scattered individual trees. Staff use a helicopter with either a lance or wand to apply herbicide at the base of the tree. Trees die over the course of several years and do not spread after successful control.

Ground-based basal bark application

Ground-based basal bark herbicide application is similar to its aerial counterpart except it is appropriate for accessible scattered individual trees.

Cut stump with ground-based basal bark application

This method cuts the tree and applies herbicide to the stump. As with non-herbicidal felling, the cut stump method is used in situations where the aesthetics of dead standing trees is an issue.

Drill and fill

Drill and fill refers to a control method where the trunk is drilled in several places and herbicide is applied in the holes. Drill and fill has mostly been superseded by basal bark application. This method is most suited to large, scattered trees rather than small/young trees.

Aerial boom spraying

Aerial boom spraying refers to using a helicopter to spray dense and extensive stands of wilding conifers. The herbicide is applied to foliage, rather than basal bark.

3.1.2 Determinants of control costs per hectare

Wilding control costs vary. It can be as little as $5–$10 per hectare to treat sparse infestations however control costs escalate over time as trees become more dense: treating dense infestations will typically cost $2,000 per hectare to aerial boom spray.

The variables that materially affect the cost of controlling wilding conifers are:

- Density of controlled trees
  - It is mechanically more expensive to control more trees in a hectare. However, control in a given hectare has a substantial fixed cost due to the costs of accessing a site. After incurring the fixed costs, control costs increase with density at a decreasing rate as it is cheaper (per tree) to control a fixed number of trees if they are more densely packed.
- Species
  - Different species require different chemical combinations with potentially different costs and may take longer to cut based on shape.
- Accessibility
- Tree size distribution
- Site weather
- Site terrain

3.1.3 Controlling trees of different densities

Control activities will be focussed mostly on outlier and scattered wilding conifers. Table 3 illustrates the mix. Outlier and scattered trees are not hugely problematic now, but will become problematic in the future. Within 15 to 30 years, land with scattered or outlier wilding conifers will become dense. These trees will cone within 10 to 15 years, sometimes as early as age four. After coning, a tree will disperse its seeds widely and easily using the wind. In this way, wilding conifers quickly overwhelm and colonise productive land and native habitats.

Table 3 Control, by density class

Dense	Intermediate	Scattered	Outlier
2%	17%	25%	55%

Source: Ministry for Primary Industries

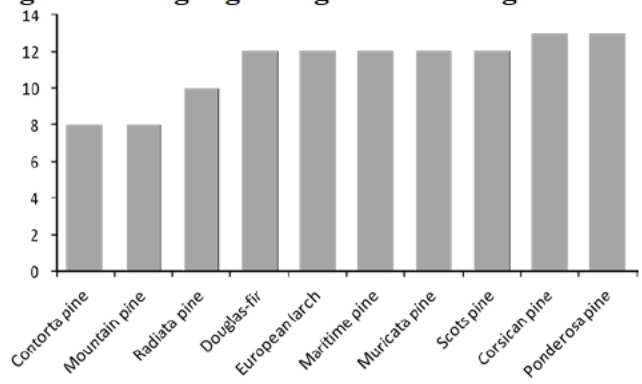
3.2 What happens when a site isn't controlled

When a site isn't controlled, outlier and scattered wilding conifers will cone, densify and spread.

Wilding conifer spread is influenced by a number of factors, including the species of tree, position and shape of the source population, wind strength and direction, frost and drought, the surrounding vegetation type and land management practices (Ministry for Primary Industries, 2014).

Most conifer species produce seeds within ten to 15 years (contorta much earlier, sometimes at age four). Seeds are easily and widely dispersed by wind. In areas with relatively light winds, seedlings tend to appear within close proximity to the seed source. Areas with strong winds can see seeds dispersed over a wide area, significantly increasing spread and colonisation of new areas. Figure 4 outlines the average number of years until seed production begins in the main wilding conifer species in New Zealand.

Figure 4 Average age of significant coning

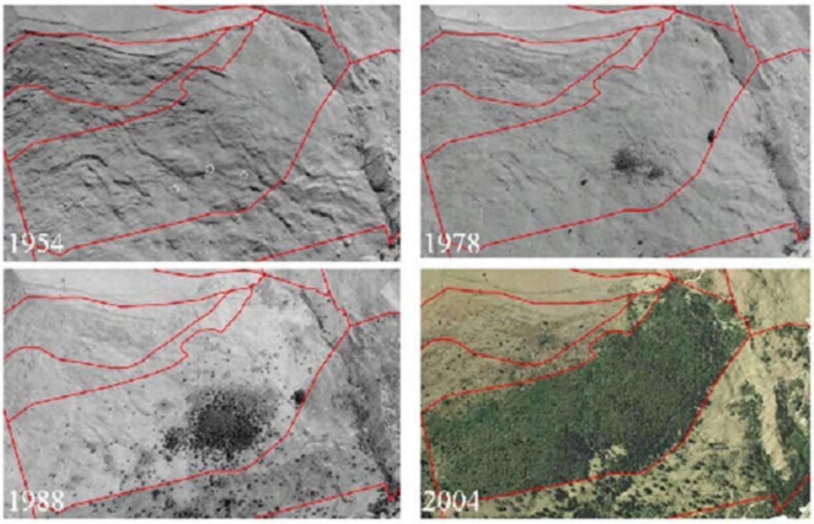


Source: Ledgard (2002)

Seeds can remain dormant for five to 10 years, although most species' seeds germinate within the first year (Ledgard, 2002). Contorta pine is one of the most prolific wilding species, as it reaches coning age within a relatively short timeframe, and is classed as an "unwanted organism" under the Biosecurity Act 1993. An unwanted organism is defined as any organism capable of causing unwanted harm to any natural and physical resources or human health. Contorta pine is classed as an unwanted organism due to its prolific spread rate, and its ability to quickly overwhelm and colonise native habitats.

The Mount Dewar example illustrated in Figure 5, below, shows what can happen over fifty years. No pines were present in 1954. By 1978 there was a small patch of scattered wildings, which spread and densified. By 2004, 24 years after the scattered wildings appeared, the entire block is densely inhabited by tall pines.

Figure 5 Mt Dewar spread of wilding conifers (1954-2004)



Source: MPI (used with permission)

3.2.1 Some land is more vulnerable than others

The Wildlands Prioritisation report[5] describes a method of prioritising wilding conifer sites. The prioritisation approach focused on the vulnerability of a site's landscape to invasion by wilding conifers. The Wildlands framework uses the invasiveness of wilding conifers and the vulnerability of different land covers and provides a national mapping of the vulnerability of different land cover types. Its vulnerability scores for LCDB cover types were used to map vulnerability to wilding conifers nationally.

Vulnerable land with a current wilding presence is highly likely to have wilding conifers spread, and quickly. Vulnerability mapping indicates that a total of 16.8 million hectares has some degree of vulnerability. 7.5 million hectares is significantly vulnerable (very high, high or moderate vulnerability). Much of the eastern South Island is highly vulnerable to wilding conifer invasion. Locations like Alexandra, Craigieburn, Dunstan, Godley, Hakatere, Kawarau, Mid Clarence, Molesworth, Northern Eyre, Pukaki, Remarkables, Shotover, St Mary/Ida, Tekapo East, Pukaki have over 80 percent of land as significantly vulnerable (LINZ, 2018).

Figure 6 shows the areas of significant vulnerability. It provides a snapshot. Land can become more vulnerable over time. This is because of increasing seed rain. For example, a farmer receiving distant spread may spend less than $10 per hectare to maintain a wildingfree property. However when neighbouring land becomes heavily infested and produces vast amounts of seed, the cost can go up

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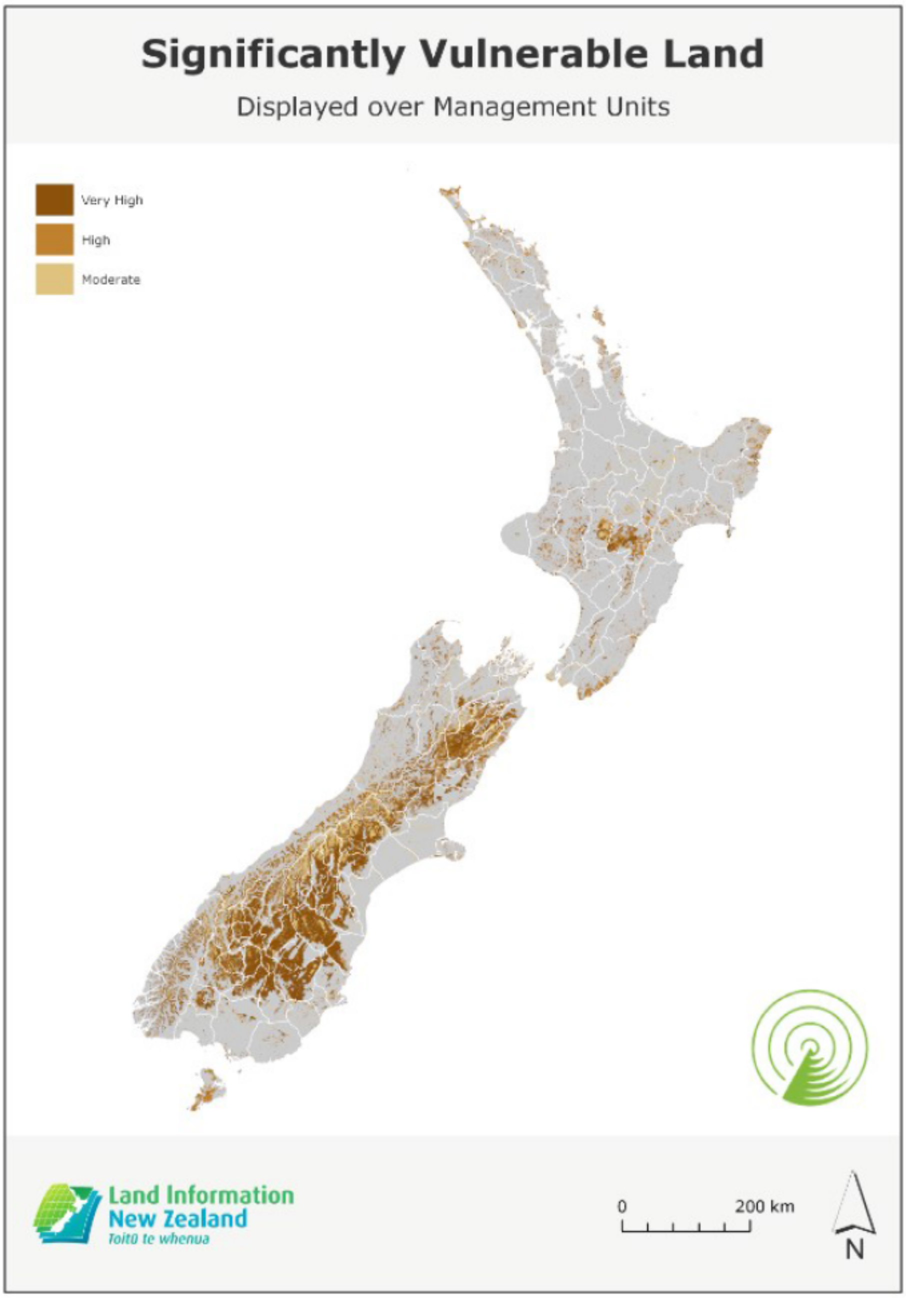
[5] Wildlands Ltd. (2016)*Methods for the Prioritisation of Wilding Conifer Sites across New Zealand*, Contract Report No. 3754a. This report was commissioned by the Ministry for Primary Industries as part of the development of the New Zealand Wilding Conifer Management Strategy (NZWCMS) 2015-2030. The report prioritises wilding conifer infestations to help direct the control effort. Wildlands identified and collected data on each of over 550 sites so the criteria could be applied. The mapping was built on the consensus of 26 experts involved in wilding conifer management.

considerably and overwhelm. For example one farmer in Hawke's Bay had costs rise to $400 per hectare to maintain his property when wilding conifers spread to his property boundary.[6]

[6] Anecdotal, per s 9(2)(a) , *pers comm.*

Figure 6 Vulnerability



Source: LINZ / Wilding Conifer Control Programme (used with permission)

4. Programme costs

This section describes what it will cost to control wilding conifers and reduce the spread.

The total quantified cost of the Minimum plus option is $64 million, which will be incurred over four years. This increases to $166 million for the Intermediate option. It falls to $8 million in the Do Nothing scenario. The quantified costs represent a combination of central government funding and funding from external contributors, including regional councils and territorial authorities.

4.1 Government investment

Figure 7 summarises the direct, fiscal cost to government over the four year duration of Phase 2.

Figure 7 Direct fiscal cost of Phase 2 of the Wilding Conifer Control Programme

Do nothing	Minimum plus	Intermediate
-	44 million	118 million

Source: MPI

4.2 Non-fiscal costs

Figure 8 shows a summary of the non-fiscal costs.

Figure 8 Non-fiscal costs

	Do Nothing	Minimum Plus	Intermediate
External contributions	7.5 million	9.7 million	22.0 million
Deadweight losses	0.8 million	9.8 million	25.8 million
Other costs (social, cultural, health)	Not quantified	Not quantified	Not quantified

4.2.1 External contributions

MPI have estimated that around $7.5 to $8 million was spent by various parties on Wilding Control in Phase 1 (which ran from May 2016 to the present). This level of spending would continue in the Do Nothing scenario, but after the four year term it would quickly tail off as landowners and councils realise the futility of attempting to control wilding conifers singlehandedly.

The existence of the Programme has enabled co-ordination of the current spend for best effect, alongside the Programme's funding. In the minimum plus and intermediate scenarios, the external contributions would increase as the fiscally-funded portion increased. So in the minimum plus scenario MPI estimates that external contributions will increase to $9.7 million and in the intermediate scenario, $22 million.

4.2.2 Deadweight loss of taxation

Most of the costs of Phase 2 will come from consumption of resources, such as labour, materials etc. But additional costs arise as a consequence of the project being financed from taxation. This cost (or rather, welfare loss) is referred to as the deadweight cost of taxation (or sometimes as a deadweight loss, or 'excess burden').[7]

The Treasury Cost Benefit Analysis guidance suggests a rate of 20% as a default deadweight loss value in the absence of an alternative evidence-based value. Thus public expenditures should be multiplied by a factor of 1.2 to incorporate the effects of deadweight loss.

There will be a deadweight loss associated with the external contribution to the control programme, which is primarily funded by regional and local councils who generate their income from land taxes/rates. Land taxes have zero deadweight loss, but arguably taxing improvements has a deadweight loss. Rates are a mixture of improvements and land, so we have applied an assumption of 10%—we are not aware of a New Zealand-based official estimate.

4.2.3 Social, cultural and other costs and risks of control activities

The control strategies rely somewhat on the time and commitment of community groups, volunteers and private landowners. The social and cultural costs of this private commitment have not been quantified in the CBA, but are significant.

The 2017 biannual survey of rural decision makers conducted by Landcare research[8] showed that wilding conifers are a recent and emerging problem for rural landowners. The great majority of affected landowners (84 percent) control them in some way, principally for reasons of kaitiakitanga.

There are also various nonfinancial/time costs associated with different types of control. Boom spraying, for example, poses a human health risk if people breathe the chemicals sprayed. Ground-based spraying also poses a human health risk due to workers potentially coming into contact with the chemicals.

The main risks associated with the methods of control are related to health and safety of the operators and harm to non-target species. However, with appropriate safety precautions, these risks are relatively low.[9] Because the health risks associated with ingestion or skin contact with herbicides bark

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[7] The rationale for deadweight loss is as follows: Taxes encourage people to move away from things that are taxed and toward things that are not taxed or more lightly taxed. Their consumption choices are distorted away from what they would prefer in the absence of taxes. The change in the mix of consumption has an adverse welfare effect which is additional to the loss of welfare resulting directly from the loss of money that is taken away in the form of tax.

[8] Landcare Research. (2017.) *Survey of Rural Decision Makers.* Landcare Research: Wellington, New Zealand. <landcareresearch.co.nz>

[9] See Department of Conservation (2014) for a discussion of the (low) human health risks associated with bark applications. (There appears to be no equivalent document discussing the risks associated with boom spraying).

applications are relatively low, and risk of harm to non-target species is negligible, these risks are unlikely to influence the recommendations of any costbenefit analysis.

The health risks associated with boom spraying are mostly associated with inhalation by nearby humans. Controllers can minimise this risk by ensuring that no one is near the spray site before commencing spraying. Boom spraying also poses a risk to non-target species. However, this risk can also be made minimal by using boom spraying only when the target species is clear from other species, carefully targeting the spray, and only using boom spraying in low wind conditions.

The risks associated with injury and death in control activities also appears to be low. There have been no deaths and no major injuries associated with the control programme to date.[10] The commercial forestry sector is, however, well known to be a high-risk industry, with most deaths and injuries associated with felling large trees. The programme should thus continue to be vigilant with using best practice health and safety.

Given that the risks to human health and safety appear to be low for status quo control activities, we have not quantified these risks as they would be highly unlikely to alter the comprehensive costs associated with control materially.

5. Control protects productivity

This chapter provides a summary of the productivity benefits associated with the control of invasive wilding conifers, along with a description of the methodology used to assess the benefit.

5.1 Invasion of conifers reduces the productive potential of land

Value-added productivity is the potential of the land to produce gross domestic product (as estimated using earnings before interest, tax, and rent (EBITR). The modelling uses a combination of land cover, land use, control and infestation data to estimate, for
"CONTROL", "PROTECT" or "SURRENDER", the:

- Impact on productivity from low value or depleted grassland
- Impact on productivity from arable land
- Impact on productivity from sheep and beef land
- Impact on productivity from horticultural land

[10] Kendon Bell. (2018). *Measuring the costs and effectiveness of controlling wilding conifers: Discussion document.* Landcare Research: Wellington, New Zealand.

5.2 Future analysis may capture additional land types

Future analysis may capture additional impacts, such as:

- Impact on productivity from commercial forestry land
- Impact on manuka honey production

The author acknowledges that controlling wilding trees on neighbouring properties is a major challenge for the forestry industry and control of wilding conifers can come at a considerable cost (the NZFOA estimates the cost of controlling wilding conifers is $29.85 per hectare of plantation forest[11]). This issue is particularly relevant for Douglas fir.

If additional obligations on forest owners from Phase 2 of the Programme induce them to change land use from forestry to grazing[12] as a means of control, there will be a marginal loss of EBITR from this change. Any land converted from forest to grazing has been estimated to come at a cost of $22 per hectare.[13] However the analysis includes no quantified impact on foresters from Phase 2 of the Programme. This is because the majority of forest owners have existing obligations[14] in relation to neighbouring properties, and how the Programme might change these or impose cost is unclear. Scaling up control works in some regions may increase foresters' obligations, or indeed it may lessen them (as neighbouring properties may be managed under a wider control scheme, where costs are shared). So increased control may raise or lower costs for forest owners.

Wilding pine incursion onto land where mānuka grows will reduce the availability of mānuka flowers for honey production. Honey production from mānuka is in Eastern North Island locations and Northland. If there is mānuka/kānuka present on sheep and beef capable land in those locations then that mānuka/kānuka may be a honey source, and might be valued at similar to sheep and beef profitability.[15] The impact of control on these potentially honey producing areas is small, because the

[11] NZFOA, *pers comm*.

[12] Sheep grazing has been identified as one method of control for wilding conifers (Froude, 2011). However the success of grazing depends on palatability of the species. The feasibility of grazing can depend on the altitude of the land - if stock, namely sheep, have to be mob stocked to eat the trees, then this will have other adverse effects as the land is above 700 m above mean sea level (s 9(2)(a), pers. comm., 2015).

[13] In Waikato. See: https://www.waikatoregion.govt.nz/assets/WRC/Council/Policy-and-Plans/HR/S32/C/Olubode-F-2015.-Sheep-and-Beef-data-adjusted-for-average-schedule-price-andexpenditure.-WRC-Report-No-HR-TLG-2015-20165.4.-Document-3344335.pdf

[14] There are obligations on forest owners to control wilding trees, but these vary by region. For example under the Southland District Plan, resource users must adopt the best practicable option to avoid or mitigate the effects of the spread of wilding pines, and within the Mountain Resource Area the planting of Douglas fir is a restricted discretionary activity. A number of the applications to plant Douglas fir in Southland have consent conditions to control wilding conifers to a radius of up to several kilometres. Forest owners who are members of the Forest Stewardship Council are required to be good neighbours, which includes controlling wilding tree spread. The New Zealand Wilding Conifer Management Strategy has an action to develop best practice regional pest management plan rules which address wilding conifer spread across boundaries without capturing appropriate plantings (Ministry for Primary Industries, 2014).

[15] A recent study into mānuka honey found the industry to be highly profitable in some areas, but akin to the profitability from sheep/beef in others, particularly where mānuka plantations were on marginal land. We have assumed sheep and beef profit margins for the 'mānuka' locations. This estimate is small in the context of the other productivity benefits, but uncertain. See: MacIntyre, P, 2017, Progress Review of the High Performance Manuka Plantations Primary Growth Partnership Programme, page 33 and 34, https://www.mpi.govt.nz/dmsdocument/21907/loggedIn

areas are in the North Island where control is not so concentrated. So the impact is small relative to the other land uses affected (potentially around one thousand hectares).

5.3 Large tracts of land will be controlled and protected, and some will be surrendered

The table below summarises the control achieved in the Intermediate scenarios. The Do Nothing scenario is almost an opposite of this, in that the vast majority of the land protected in the Intermediate scenario is surrendered in the Do Nothing scenario.

Figure 9 Productive land controlled, protected and surrendered in the Intermediate scenario

Land affected	CONTROL Hectares	PROTECT Hectares	SURRENDE R Hectares	Note
All land types	1500000	7,250,000	250000	Note: this is 96% of the current infestation
Sheep	*75866*	*366685*	*1640*	Note: this is sheep and beef, moderate value
Horticulture	*618*	*2986*	*15*	Note: High value but low volume
Low Grass	*339882*	*502887*	*77246*	Note: this is low value, low stocked (mostly sheep grazing) high country land
Crop	*1607*	*7765*	*2*	Note: This is arable cropping land
Biodiversity	*1500000*	*7250000*	*250000*	Note: the entire vulnerable area attracts a biodiversity value
Fire	*1500000*	*1232500*	*250000*	Note: dense infestation only counted as impact

Canterbury irrigation catchment	*5516*	*261905*	*0*	Note: Only captures infestation into high country grassed areas
Hawkes Bay irrigation catchment	*5*	*22671*	*5*	Note: Only captures infestation into high country grassed areas
All hydro catchments	5520	*similar to the low grass area protected*	*similar to the low grass area surrendered*	Note: Only captures infestation into high country grassed areas

5.4 Productivity impacts rely on assumptions about wilding growth and spread

The analysis of impacts on productivity applies a 50 year projection, from which a perhectare value of the impact of control (and conversely, failure to control) is estimated. Each different type of land use has a different value of control attached to it. There are common assumptions used in the projection. These common assumptions are:

- Extent of productivity loss as a consequence of wilding conifer invasion
- Time (in years) for productivity loss to be complete if the land is surrendered
- Time (in years) for productivity to be regained to full potential after first round of control

Each of these assumptions varies according to the density of the existing wilding conifer invasion on site. Table 4 below summaries these assumptions.

The assumptions in the table can be explained as follows. Say there is a hectare of productive land. If this hectare has dense wilding conifers that are surrendered, the analysis assumes that all of this hectare's productivity will be lost and this will take less than a year. However if the land is controlled (and the dense trees are removed) the land might take five years to return to full productivity, as there will be time needed for stumps to rot down and grass to regrow and so on.

Table 4 Productivity loss generic assumptions

Density of existing wilding conifers	Extent of loss	Time for productivity loss to be complete if the land is surrendered	Time for productivity gain to be complete once control has started

Dense	99.9%	< 1 year	5 years
Intermediate	30%	5 years	2 years
Scattered	20%	15 years	2 years
Outliers	2%	30 years	< 1 year

5.5 How productive land is impacted varies by type

The paragraphs below examine the different impacts of wilding conifer control on the different types of land.

5.5.1 Low value or depleted grass land

Tall tussock grassland, depleted grassland and low-producing exotic grassland are very highly vulnerable to wilding conifer invasion (Wildlands, 2016). Depleted grassland and lowproducing exotic grassland can be suitable as grazing land in some instances (but not all).
The analysis has only counted land as potential suitability for grazing if it is class 6 or 7 in the Land Use Capability Classification (LUC). The analysis does not include tall tussock grassland as productive land as it is seldom used for grazing and is mostly held within the conservation estate.

The impacts of wilding conifer control on depleted grassland and low-producing exotic grassland have been estimated applying an estimate of EBITR per hectare from sheep and beef grazing. The value applied as the estimate for the full productivity of this class of land is $37 per hectare, per annum. This is based on the Sheep+Beef NZ farm benchmarking series for Class 1 High Country South Island, forecast 2017-2018.

The model applies 50 year present values (i.e. it cumulates the $37 per hectare per year, and discounts them). To illustrate how the values vary according to density, the table below shows the present value of land impacts associated with low value or depleted grassland.

Table 5 Illustration of variation in PVs - Low Value Grassland PV assumptions according to density class

	Dense present value	Intermediate present value	Scattered present value	Outlier present value
Control PV	$455	$169	$113	$12
Protect PV	$582	$552	$478	$395
Surrender PV	-$582	-$552	-$478	-$395

5.5.2 Arable land

The impacts of wilding conifer control on arable land (or short rotation cropland) have been estimated applying an estimate of EBITR per hectare for arable farming. The value applied as the estimate for the full productivity of this class of land is $2136 per hectare, per annum. This is based on a 2012 figure from the MPI Farm Monitoring series[16] and inflated to 2018 using the food price index in the Reserve Bank of New Zealand inflation statistics dataset.

5.5.3 Horticultural land

Horticultural land has a very low vulnerability. However some land that already has wilding conifers on it has been identified as being horticultural land. This land is mostly in the Marlborough region, but also Hawke's Bay and elsewhere. The impacts of wilding conifer control on horticultural land have been estimated applying an estimate of EBITR per hectare for horticulture of all types. The value applied as the estimate for the full productivity of this class of land is $6519 per hectare, per annum. This is based on a median value of all types of horticulture from the MPI Farm Monitoring series.[17]

[16] Ministry for Primiary Industries, Farm Monitoring Report 2012 - Horticulture Monitoring: Canterbury Arable Cropping

[17] Ministry for Primiary Industries, Farm Monitoring Report 2012 - Farm Monitoring Report 2012 - Horticulture Monitoring: Pipfruit, Viticulture, Kiwifruit.

5.5.4 Sheep and beef land

The impacts of wilding conifer control on exotic grassland have been estimated applying an estimate of EBITR per hectare from sheep and beef grazing. The value applied is $297.84 per hectare, per annum. This estimate was based on the Sheep+Beef NZ farm benchmarking series. It was generated using a median value for a selection of classes of land likely to be in the zones affected by wilding conifer invasion. The forecast figures for 2017-2018 were applied to generate the median value.

6. Control protects water

Wilding conifers reduce surface flows and aquifer recharge in water-sensitive catchments. Less flow means less water for farmers' irrigation needs, hydroelectric generation, or outdoor recreation use. And less water for those plants and animals that live in and around our rivers.

This reduction of water due to wilding conifer spread impacts on water availability for irrigation and electricity generation in water sensitive areas like Southland, Otago, Canterbury and Marlborough. Climate change is likely to increase wilding conifer spread and reduce water yields in regions that are experiencing hotter and drier conditions, and water shortages. As well, water quality and water quantity are required to sustain native plants, animals and ecosystems. Controlling wilding conifers to maintain water yield is a compelling argument.

6.1 A significant impact on water yield

Where pasture land becomes covered in wilding conifers, this reduction in annual water yield has been shown to range from 30 to 81 percent (with the upper end of that range recorded in dry South Island sites).[18] For example one study at Glendu forest in Otago measured the effects of converting tall tussock grassland to radiata pine. Results showed a water yield reduction of 40 to 45 percent, 22 years after the trees were planted. It is expected wilding conifers will have similar impacts on water yields compared to planted trees.

To estimate the approximate reduction of water yield during low flow events on a national scale and account for some of the regional variability we have applied the assumption used in Scion (2015), which was based on three South Island catchments (Glendu, Kākahu and Berwick) that were part of earlier catchment-based experimental water-afforestation studies. The average reduction in water yield during low-flow conditions was approximately 16 percent.

Scion noted that the 16 percent assumption was possibly conservative as the reduction in water yield from dense wilding conifer stands could be higher than from afforestation as wilding conifer stands might have a much higher interception effect, because of their rougher canopy surface. In addition wilding conifers might occur in the far upper reaches of catchments and therefore can affect low flow yields more significantly than mid-altitude afforestations.

Most wilding conifer infestations are currently sparse and do not yet have a significant impact on water yields. As wilding conifers grow and spread they will form dense stands and there will be increasing impacts on water yields over time.

The calculation approach starts with an attempt to overlay areas of current wilding infestation with current water shortage areas (this was done manually, by sight rather than using mapping technology). The calculation assumes that if wilding conifers are present on high grassland in the region, then that grass land will become invaded as it is highly vulnerable. If Controlled, the land will have 16 percent of

[18] Data from a number of catchment studies have showed that where pasture has been replaced by radiata pine forest, there was a reduction in annual surface water yields of 30-81%.

its water restored over five years. If Protected, it will not lose 16 percent of its water. If Surrendered, it will start losing 16 percent of its water after 12 years, ie the water loss repeats from year 12 to year 50.

6.2 Wilding conifer control protects water for irrigation

The table below summarises the impact of control on the value of irrigation water. The table shows that the intermediate scenario has an impact on the farm gate value of water worth almost $2.4 billion over 50 years.

Table 6 Impact of control on irrigation water, NPV 50 years

Do nothing	Minimum plus	Intermediate
-1.9 billion	1.7 billion	2.0 billion

Irrigation water is a valuable commodity and can be valued in a number of ways. The value of irrigated land that could be affected by wilding conifers ranges from $1200 to $10,000 per hectare. The portion of land irrigated in each management area with wildings currently present ranges from 1 to 17 percent.

We applied MPI's recent *Value of Irrigation* study authored by NZIER to put a per-hectare value on irrigation. This study allowed us to apply a region-specific value of water.

To generate the results shown above, we have used a conservative approach whereby only the driest areas with significant potential for dense wilding invasion are included. The illustration below, from the Ministry for the Environment's water stress mapping shows the areas where irrigation water is most at risk from upstream consumption.

Areas in red are areas where, if water is taken upstream, the effect on downstream flows will be greater than the upstream take. When wilding pines grow in headwater grasslands and suck 16 percent of the available water, the water available for irrigation downstream will be curtailed by at least as much.

6.2.1 Analysis only includes catchments experiencing very high water stress

Overlaying this water stress map with maps of present infestations of wilding conifers highlights that the Canterbury and Hawke's Bay catchments are both extremely vulnerable to wilding conifer invasion and are suffering very high levels of water stress. Southland, Central Otago and Marlborough are vulnerable, but across smaller areas of land. To be conservative, we have only modelled Canterbury and Hawke's Bay.

Figure 10 High water stress areas (highest stress shown in red)

Source: Ministry for the Environment

6.2.2 Treating wildings around Canterbury and Hawke's Bay saves around 8 percent of the value of irrigation water in those districts

The annual impact of wilding conifer control on irrigation in Hawke's Bay and Canterbury is around $28.7 million per year, a present value of $24.4 billion over 50 years. So the loss of $1.9 billion of water in present value terms represents around 8 percent of the value of irrigation in those districts.

6.3 Wilding conifer control protects water yield for hydroelectricity generation

Dense wilding conifers are present in four of the six most significant hydroelectricity catchments in New Zealand: Tongiriro, Waitaki, Clutha and Manapouri. Infestations in the central North Island also affect the water flowing through the Waikato hydro schemes. If left uncontrolled, wilding conifers will spread and densify further into these catchments.

Over a fifty year horizon, the value of wilding conifer control in relation to hydro generation is $961 million in the Intermediate scenario. Doing nothing amounts to a loss of $955 million.

6.3.1 Catchment-based analysis of hydro impacts

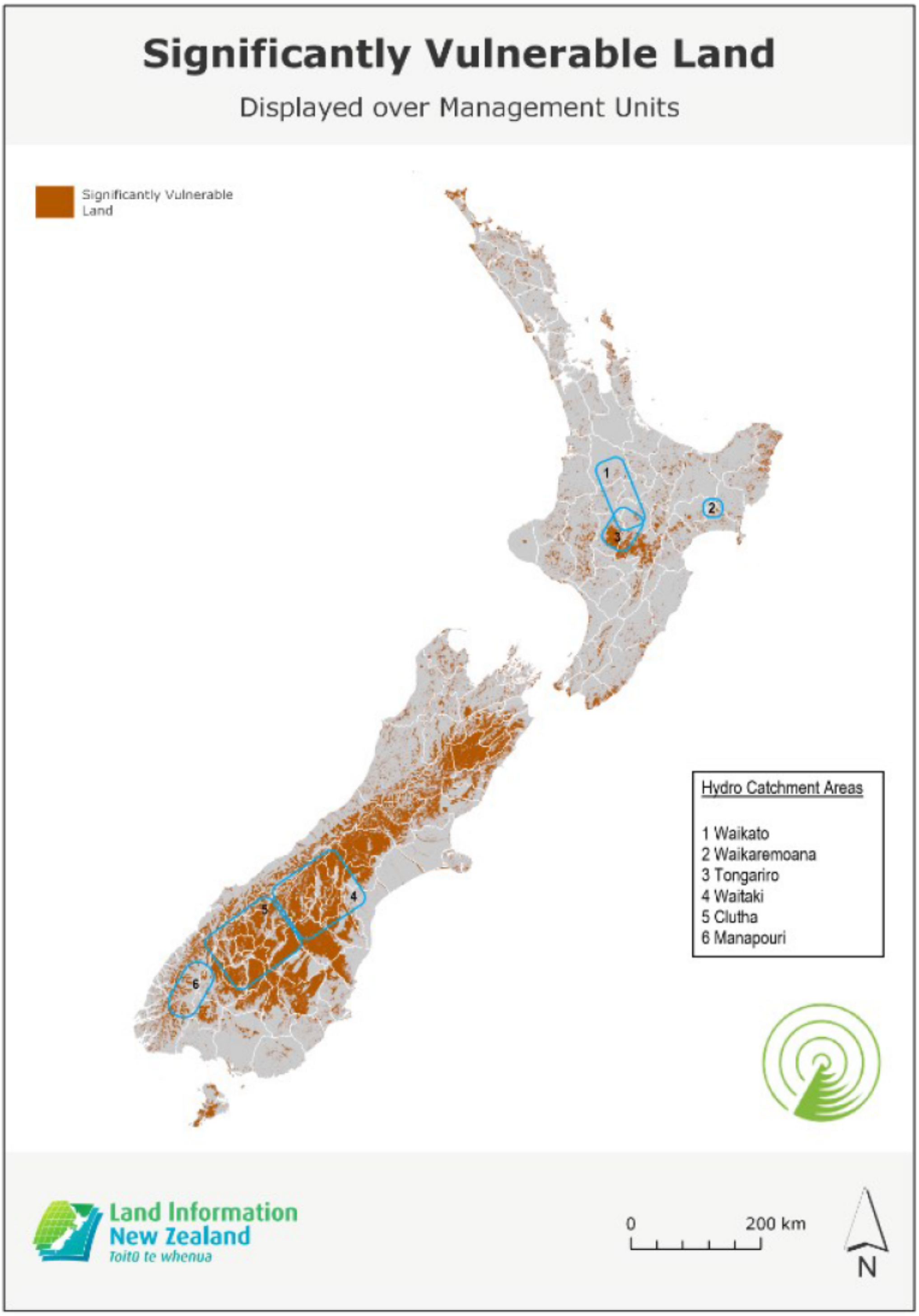
The hydroelectricity generation impacts were generated using a catchment by catchment analysis. This analysis depended on the following inputs:

- An assumption about the impact of wilding conifer infestation on water availability, relative to grassland or alpine tussock etc. We have applied the 16 percent assumption described in the earlier section on irrigation impacts.
- An analysis of the value of water used in the production of hydroelectricity. We have applied an estimate of hydro resource rent (which, as a profit measure, is broadly equivalent to the EBITR figures we have applied to generate the impacts on agricultural production and is equivalent to the contribution to GDP from the activity of hydro generation). The estimate of resource rent was sourced from the Statistics New Zealand Water Resource Rent series. It is an annual figure.
- An allocation of the total value of water to each wilding-affected catchment, which varies according to price and generation capacity.
- Calculation of present values of resource rent reductions over a fifty year period.

The location of hydroelectricity catchments in the context of land that is significantly vulnerable to wilding conifer infestation is shown in Figure 11 below. Hydroelectricity catchments are shown with blue markings on the map.

Figure 11 shows that the Waitaki and Clutha are particularly affected by wilding conifer spread. All but the Waikeremoana catchment (which is mostly already covered with dense forest) will be affected. We have conducted a catchment-by-catchment analysis of impact.

Figure 11 Wilding conifer spread into hydro-generation catchments



Source: New Zealand Wilding Conifer Control Programme

The present value impact on resource rent (over fifty years) is shown below. While the Waikato values are very high, the most impacted catchments are the Clutha and Waitaki catchments when there is no control. This is because these catchments have enormous areas of high country grassland that generate water for hydro catchments that could be invaded.

There are several factors that contribute to why water has different values by catchment:

- The value per hectare of vulnerable grassland, which is driven by the number of hectares of vulnerable grassland;
- The amount of water in a catchment;
- The amount of work a unit of water does, this is related to how much energy the unit of water produces through each hydro station, and is proportional to the height the water falls at each generation station and the efficiency of each station;
- The price received by the hydro station for its electricity generation.

Table 7 Present value impacts on hydroelectricity resource rents, per hectare of high grassland controlled, protected or surrendered, by catchment.

	CONTROL value (PV of resource rent impact over 50 years)	PROTECT value (PV of resource rent impact over 50 years)	SURRENDER value (PV of resource rent impact over 50 years)
Waitaki	$232.13	$154.38	-$154.38
Waikato	$7,124.26	$4,738.04	-$4,738.04
Manapouri	$364.12	$242.16	-$242.16
Clutha	$191.29	$127.22	-$127.22
Tongariro	$175.70	$116.85	-$116.85

Waikaremoana	$0.00	$0.00	$0.00

Source: Sapere Research Group

7. Operational impacts of Phase 2

Currently there are approximately 200 FTE (project managers and contractors) directly engaged in the control of wilding conifers across New Zealand as a result of Phase 1 of the Wilding Control Programme.[19,20] This will be scaled up considerably if the Programme is extended into Phase 2. The workforce will be located almost exclusively in the regions.

We have assumed that the labour patterns established in Phase 1 will be extended nationally in Phase 2. The driving assumption behind our calculation is that 8.8 full time equivalent (FTE) contractors will be needed for every $1 million on control spent (as was the case in Phase 1). In addition to contractors, there are contract management and project management staff needed to oversee the control and maintenance efforts.

All labour impacts are calculated in accordance with the NZ Treasury's CBAx modelling assumptions, and include marginal impacts on household income, government tax benefits and social benefits of employment. A detailed description of the labour calculation is included in Appendix 1.

Figure 12 below summarises the labour impacts over the four year period of Phase 2. The Intermediate scenario has a workforce of 865 contractors and 13 management staff. The Minimum Plus scenario assumes a smaller workforce, of 240 contractors and 4 management staff. The ratio of management to staff has been held constant in the modelling, it may be the case however that more managers are needed in the Intermediate scenario relative to the Minimum Plus scenario, as the Programme scales up from being a series of localised activities to being nationally coordinated.

Figure 12 Operational impacts

	Do Nothing	Minimum Plus	Intermediate
Full Time Equivalent staff	0	244	878
Jobs and earnings impact	$ -	$0.8 million	$3.4 million

[19] National Wilding Conifer Control Programme Operation Advisory Group, Wilding Conifer Control Workforce Background Discussion Paper, 11 October 2017

[20] The number of FTE involved in the support services to wilding conifers control, such as research and herbicide manufacture, is not apparent in the statistics.

Government benefits of employment (e.g. social impacts of employment and avoided jobseeker payments)	$ -	$3.1 million	$13.5 million

Source: Sapere Research Group

7.1 A variety of roles will need to be filled

7.1.1 The project management workforce

The project management workforce consists of regional project managers, contract managers, coordinators, and quality assurance. They will be tertiary qualified but will likely be recruited from similar jobs (perhaps in regional councils or DOC). Anecdotally, programme fund-holders and contractors report that skills shortages are already evident at the experienced 'project manager' level. Employing these people will thus create a small impact on marginal household incomes ($14,264 per FTE over the four year term).

7.1.2 The contractor workforce

The contractor workforce consists of ground and aerial crews, with the following characteristics

- The core workforce may be characterised as almost exclusively male, in the peak 'working age' group (25-50years).
- All will be trained 'on the job'. There is no formal apprenticeship system or qualification. While there are several forestry industry certifications relevant to wilding conifers, there are no wilding conifer-specific training or qualifications based on nationally agreed industry standards.
- There is a range of job roles involved directly in the operational control of wilding conifers. An indicative list is as follows:
  - Certified Ground Crew - Chainsaw Operators/Tree Fellers; Spray Back-pack Operators[21]
  - General Ground Crew – eg. loppers
  - Machine Operators (eg.bulldozers)
  - Transporters (Chemical)
  - Helicopter Pilots
  - Helicopter Company Operators (Wand Operators, Loaders, Drivers)
- The core experienced workforce tends to be drawn from other weed spraying businesses, and animal control professions – in particular possum control. In the South Island at least, perhaps counter-intuitively, there are few in wilding conifers control contracting with a background in

[21] There are other job roles in what could be grouped as the 'support services' to wilding conifer management, such as herbicide development, control equipment design and manufacturing, machine maintenance – air and ground, technologies and innovation – hardware such as Unmanned Aerial Vehicles and software such as mapping applications, and research activities (laboratory and field).

forestry (silviculture). In peak season, the supplementary ground crew contracting workforce is made up of tertiary students, and working holiday makers among others.

- The peak season generally traverses September to March when the weather is drier (although herbicides have improved in recent times to be able to carry out some work in wetter weather). Snow is the main restriction to the season in the south.
- The ground crew contractors charge around $40-50 per hour for 'non-mechanical' work and around $45-55 per hour for workers with chainsaw certifications and skills. On average they would earn approximately $50,000 per annum.

With regard to contracting specifications in wilding control, there is a great deal of variation across the country. Greater consistency of contracting specifications nationally is a preferred outcome over time, and will be informed by good practice, competency standards, training and certification.

In terms of qualifications there is anecdotal evidence that most, but not all, workers hold all necessary basic certifications to carry-out ground operations using herbicides. Apart from minimum requirements, there is scope to look at productivity improvements through more training and certification – above and beyond the minimum.

Although not impossible, it is difficult to estimate the number and type of job roles required to deliver on the national strategy out to 2030 from year to year. The nature of infestations change over time, due to control work carried out. For example, based on estimates supplied by one fund-holder (ECAN), around 100,000 ha of sparse wilding conifers can be controlled over 3 days, via aerial wanding from helicopters, with 2 FTE workers (pilot, wander). This estimate may not hold in other parts of the country depending on the topography where the infestation is, and the density of the infestation differing between control areas.

7.1.3 Volunteer Workforce

Volunteers already contribute a significant amount of time to wilding control, and under the proposed control programme there would be potential to develop initiatives to expand volunteer involvement. Volunteer models already exist that could be used as templates, such as programmes developed by the Department of Conservation and community trusts.

7.1.4 Sourcing skilled workers will be a focus

The current programme has identified several good practice and 'up-skilling' opportunities to help close the existing skills gap, and to support positive outcomes for the health and safety system. For example, working alongside planting programmes to provide continuity of work (to allow contracting firms to retain staff year-round).

8. Other impacts of control activity

8.1 Control will protect biodiversity and landscape values

Through competition for light, water and nutrients wilding pines can have marked to catastrophic effects on indigenous biodiversity, including plants, invertebrates and freshwater species. These effects, while generally local, could potentially cause at least local extinctions or even loss of some threatened native species with very restricted distribution. The native species most at risk are some fish, reptiles and insects. Many native plants have very restricted distributions too (there are approximately 2,500 vascular plant species in New Zealand[22] and of these 8 have become extinct and 180 are listed as endangered list[23]) however, there is little to no evidence of plant species extinctions occurring anywhere in the world as a result of invasive plants[24].

Although mature and old growth native forests and extensive wetlands are resistant to invasion by most conifer species (Douglas fir is less light dependent) but many unique ecosystems are highly vulnerable. Throughout New Zealand about 70 naturally rare ecosystems have been identified and about three quarters of these are potentially threatened by invasion from wilding pines including a zone above the current tree line for an additional 300 metres of altitude[25]. These include such highly valued areas as:

- alpine herb fields
- dry Tussock lands
- geothermal areas
- the volcanic plateau
- the South Island ultramafic mineral belt
- Coromandel scrub lands
- coastal dune lands, headlands and cliffs
- the Rangitaiki frost flats
- seasonal wetlands.

Each of these ecosystems contains unique species found nowhere else in the world. However, most of these at-risk species are not iconic and would be unknown to, or probably not highly valued, by most New Zealanders. For example, most of the plants at greatest risk are herbs.

[22] http://www.nzpcn.org.nz/page.aspx?flora_vascular

[23] Conservation status of New Zealand indigenous vascular plants. (2012) Peter J. de Lange, Jeremy R. Rolfe, Paul D. Champion, Shannel P. Courtney, Peter B. Heenan, John W. Barkla, Ewen K. Cameron, David A. Norton and Rodney A. Hitchmough

[24] Downey PO, Richardson DM. 2016. Alien plant invasions and native plant extinctions: a six-threshold framework. AoB PLANTS 8: plw047; doi:10.1093/aobpla/plw047

[25] s 9(2)(a) , Landcare Research, *pers comm*

Soil and soil fauna are also profoundly altered when wilding conifers replace native ecosystems and will restrict the extent to which native species can re-establish.

8.1.1 The impact

MPI estimates that Crown agencies, local government, landowners, and trusts spent $7.5 - 8.0 million over the four year duration of Phase 1. Of this, the amount raised by trusts was around $1.35 million. There are around 20 community groups around the country who contributed to this spending. During Phase 1, 1.74 million hectares of wilding invaded land underwent control operations. Taking the $8 million of regional contribution over that period as indicative, the biodiversity value associated with controlling invaded land could be in the range of $4.60 per hectare controlled.

In the intermediate scenario, 1.6 million hectares is controlled, including 295,000 hectares of dense or intermediate density trees. Preventing these dense trees from establishing over the vulnerable 7.25 billion hectares of land that is protected would translate to a positive impact on biodiversity values of $429 million over the 50 year projection.

In the Do Nothing scenario, at risk is over 7.5 million hectares of significantly vulnerable land. The negative impact of this invasion on biodiversity values would be $331 million in present value terms.

8.1.2 We have applied a conservative valuation of biodiversity

Following a review of the available literature, our analysis has applied a lower set of values than has been applied in earlier studies. Our analysis looks at behaviour as potentially indicating a suitable valuation. For example the amounts raised from the community or contributed in voluntary control work to address wilding conifers in Phase 1 of the Programme. This regional contribution provides a possible indication of the values held by communities because these contributions are likely to be strongly influenced by concerns about landscapes with some also focused on biodiversity.

This is very much a conservative, lower bound of biodiversity values. Our discussion below summarises the available literature and indicates why we have opted for conservatism in this estimate.

8.1.3 Stepping behind the values in previous studies

To estimate the potential impact of wilding conifers on biodiversity values, the 2015 Scion report extrapolated from a choice experiment which focused on the Mackenzie basin by Kerr & Sharp (2007)[26]. The Kerr & Sharp study analysed people's preferences for a proposed wilding conifer control programme which had amongst its outcomes conserving three endangered native species in the basin, Hebe cupressoides (plant), Brachasois robustus (grasshopper), and Galaxias macronasus (fish). Scion believed this study was the only estimate of biodiversity values from a proposed wilding conifer control programme done in New Zealand. We believe that is still the case.

Scion used the Kerr & Sharp study and scaled up from its findings for the Mackenzie basin to a New Zealand valuation of value from controlling wilding conifers. It calculated an aggregated willingness-to-pay of $91 million per year for five years. Scion used a 10 percent discount rate to estimate a present value of $866 million. Kerr & Sharp's estimates encompassed both use values such as recreation and

[26] Kerr, G. and Sharp, B. (2007). *The Impact of Wilding Trees on Indigenous Biodiversity: A Choice Modelling Study.* AERU Report 303. Lincoln, NZ.

non-use values such as existence and bequest values. Scion stated that the aggregated values should be considered as indicative and not absolute dollar values because the base data was not a representative sample for the national level.

In 2018 Kendon Bell of Landcare Research critiqued the Scion approach in a paper titled "Measuring the costs and effectiveness of controlling wilding conifers". He used Kerr and Sharp (2007) as a starting point and calculated that NZ households would be willing to pay approximately NZ$1,114 million in present value terms for a management programme that prevented the extinction of the threatened three species. He made two adjustments to Scion's approach which approximately cancelled each other out. He also noted that his estimate may underestimate of the value of a successful management programme because there were potentially more species threatened by wilding conifers and New Zealanders incomes has increased in the decade since the Kerr & Sharp study was completed.

To compute an estimate of a nationwide value, these analyses needed to rely on Kerr & Sharp's original work and extrapolate from that. They also used another study to assume that half of New Zealand households had zero willingness-to-pay while the other half had a positive willingness-to-pay[27]. Values were then adjusted for inflation and growth in households to estimate national biodiversity values. These estimates are therefore, as Scion noted, only indicative.

We concur with Scion and Bell that there is considerable uncertainty about these estimates. We note that the Kerr and Sharp study involved holding two small focus groups of 10 people each to identify attributes of high country wilding conifers. These focus groups appeared to show that members of distant communities didn't view wilding pines as a problem that would have negative impacts on them, or which they would pay to remedy. These people also indicated a strong preference for photographs of scenes with wilding conifers in them rather than those without. This may point to a real difficulty in separating out the components of New Zealanders views about wilding conifers if they are questioned without any prompting or information. A significant proportion of that concern seems to be bound up with landscapes and attachment to familiar landscapes. However, a material proportion could actually prefer landscapes with conifers[28]. This is probably very much the norm across New Zealand where knowledge of wilding conifers or species that may be affected by them is low. For example, a recent MPI survey revealed only 2 percent thought that biosecurity affected New Zealanders personally (though 60 percent thought biosecurity was important)[29].

Kerr and Sharp's actual choice experiment involved 165 Canterbury people in four groups. They were provided with comprehensive information about the distribution, impacts and control of wilding pines, as well as information on the individual species at risk from wilding conifers in the Mackenzie Basin. Their attitudes differed from those in the earlier focus groups and showed a more consistent willingness-to-pay for wilding control across the four groups of Cantabrians. So it seems knowledge and awareness about the problems associated with wilding conifers are very important to people's willingness to pay to protect certain species. In our view this means that the extrapolation

[27] Morrison (2000)

[28] Greenaway, A., Bayne, K., Velarde, S. J., Heaphy, M., Kravchenko, A., Paul, T., Samarasinghe, O. & Rees, T. (2015) Evaluating the (non - market) impacts of wilding conifers on cultural values. Landcare Research contract report LC2396. Auckland: Landcare Research, Scion

[29] Biosecurity 2025 public survey report mpi.govt.nz/dmsdocument/29852 [30] Canterbury Regional Pest Management Strategy

from this study to a New Zealand wide[30] view is debateable as it assumes a level of knowledge that does not exist.

There are a wide variety of concerns where people on average have poor level of awareness and greater awareness would affect their views and willingness-to-pay, for example, water or air quality. If people had greater awareness of a range of problem issues perhaps their willingness-to-pay to address them could be carefully tested to distinguish those issues they prioritised from those they didn't, given their disposable incomes. However, given the high levels of interest of New Zealanders in protecting at least iconic biodiversity such as kakapo, kokako and kiwi, there is some national value ordinary New Zealanders attach to biodiversity. The national spend on all biodiversity initiatives may be indicative of a household valuation. Budget 2018 voted $182 million over four years for biodiversity initiatives (including wilding conifer control in Phase 1), $45 million per year. If a voluntary, community contribution of a further 20 percent of that amount can be expected, then New Zealand's spend on all biodiversity is around $54 million per year - roughly $30 per household from our 1.6 million households. Again, this is substantially lower than the $70 - $140 per household just for the willingness to pay for the protection of the three native species estimated by Kerr & Sharp.

8.2 Control will protect social and cultural values, but the extent of these values is unknown

We have not included a quantification of the impact on cultural values. This is partly because no quantification input exists, and partly because a recent study of cultural values impacted by wilding conifer spread indicated both positive and negative impacts with no overall tendency in either direction. The study indicated that the cultural values were not separable, as they were highly context-specific. That is, cultural values are enacted nationally and locally, in specific ways at specific sites, so values take different meanings depending on context. A summary of that study is included at Appendix 1.

We note there may be a social and cultural gain to people from knowing that wilding trees have been prevented from spreading and encroaching on to indigenous habitats and landscapes.

8.3 Wilding conifer control reduces fire control costs

Wilding conifer control avoids spending on fire prevention; if wilding conifers were to spread uncontrolled then to reduce the risk of fire, significant effort would need to be put into suppression and pre-suppression activities. Certainly we would expect that land owners where dense and intermediate stands of wilding conifers had established might eventually be prompted to invest in clearing fire-breaks and other methods of fire suppression and presuppression instead of facing the risk of destructive fire. That is, prevention is a 'least cost' activity. Yet, there is no evidence that landowners are currently invest in fire prevention on wilding-conifer infested land other than perhaps insurance (Velarde et al, 2015).

We have applied avoided prevention expenditure to estimate the impact of wilding conifer control on costs. Typical prevention expenditure includes publicity campaigns alerting the general public and business about the consequences of wildfires; fuel management activities such as monitoring the density of forests, grass and scrub lands; patrols; and data recording (BERL, 2009).

In 2009, BERL estimated the annual cost of wildfires in New Zealand (BERL, 2009). As part of that report, BERL reported annual statistics from the New Zealand Forest Owners Association (NZFOA) and the New Zealand National Rural Fire Authority on the per hectare cost of fire prevention.[30] The per-hectare cost in 2008 was estimated at $15.48 per stocked forest hectare. Inflated to 2018, this per hectare cost is $18.45 per stocked forest hectare. This cost might be similar for a dense stand of wilding conifers (although there willbe differences in the cost of access), if landowners invested in prevention.

Potentially due to the greater value of the asset at risk, fire protection/prevention costs for plantation forests are considerably higher than for grasslands (Velarde et al, 2015). The BERL report does not state an equivalent fire prevention cost for grasslands, so it has not been possible to state with any certainty what fire prevention might cost if the land was retained as grassland. Therefore the prevention cost difference between dense and intermediate wilding conifer forest and grassland could be anywhere in the range of $0 - $18.45 per hectare.

8.3.1 The impacts

The savings in fire prevention costs as a consequence of control are shown in Table 8. The calculation assumes that the savings are applied to any density of trees. In reality it is dense or intermediate infestations which are most risky for fire; over the long term (50 years) all stands of wilding conifer trees become dense.

Table 8 NPV avoided fire prevention costs (50 year projection)

Do Nothing	Minimum Plus	Intermediate
-$1. 3 billion	$ 494 million	$ 654 million

Source: Sapere, using data from BERL (2009) *The Economic Cost of Wildfires*

This figure provides a minimum estimate of impact of control, as it assumes that landowners invest in prevention instead of allowing fires to occur. If there was insufficient suppression and pre-suppression expenditure associated with managing the increased fire risk from wilding conifers:

- The risk of fires might increase overall and we can expect a large negative impact. We cannot quantify the potential increase in the number of fires driven by the spread of wilding conifers or predict the sites where fires might occur, so we are not able to quantify the additional fire risk.
- Wild fires from invasive pines have been shown to increase the severity of wild fires. For example, the replacement of natural fynbos vegetation with pine plantations in the southern Cape, and the

[30] This data was based on research by the NZFOA on aspects of rural fire management in plantation forests. This research included two surveys of their members. The first survey covered fire administration, prevention, preparedness and suppression activities and associated expenditures, fire occurrence reporting, and loss/damage information. It had responses from 61 organisations from 35 major NZFOA members, representing 60 percent of the total net stocked area. Based on the total number of hectares of NZFOA's members, and the total spending on wildfire prevention, the survey calculated fire prevention costs per hectare. The second survey focused on relative trends in fire protection expenditure over the past three to four decades.

subsequent invasion of surrounding land by invasive pine trees, significantly increased the severity of the 2017 Knysna wildfires.[31]

- Currently there are 735 hectares of dense or intermediate wilding infestation adjacent to land marked as 'built up or settlement area' (659 in the South Island, 76 in the North Island). This current infestation has a risk to human life and property. 240 hectares of this forest would be controlled under the Intermediate control option.
- Rural fire experts at Scion were consulted as part of the Scion 2015 CBA. The experts estimated the costs of fighting fires in wilding conifers (NZ$ 1000-2000/ha). (This estimate was higher than grassfires (NZ$500 -1500/ha) but lower than plantation fires (NZ$1500-3000/ha).

8.4 Control may have no negative impact on carbon (so no values have been included)

Removing trees from a site means that site sequesters less carbon dioxide, particularly if the site is turned to grazing land rather than forest. Because wilding conifers are categorised as a weed tree there is a complex relationship between clearing them and the financial obligations that arise under the ETS for the various parties.

- New Zealand's commitments under the United Nations Framework Convention on Climate Change and the Paris Agreement include targets to reduce greenhouse gas emissions by 5% below 1990 levels by 2020 (the 2020 target) and 30% below 2005 levels by 2030 (the 2030 target).The Emissions Trading Scheme (ETS) is New Zealand's key policy tool for reducing emissions and meeting our emission reduction targets.
- The ETS and international agreements determine whether any liabilities arise from clearance of major infestations of wilding pines.
- Wilding forests are ineligible to be registered as post-1989 forests[32] in the ETS, so new wilding conifer forests have no value.

Also, allowing the spread of wilding conifers has the following negative impacts:

- The presence of those trees will prevent other, more productive uses from occurring (including the planting of exotic or indigenous forests, which can be entered into the ETS).
- Wilding conifer species are often the wrong tree species for carbon capture. They do not grow fast, tall, or capture much carbon compared to other more suitable tree species. Some species on difficult sites may not even reach a height of 5 metres that is the required definition of an ETS forest.
- Wilding conifers that originate from commercial plantings are usually scattered and it takes a long time to establish a forest area compared to a planted stand.

[31] https://phys.org/news/2018-09-invasive-fueled-south-africa.html

[32] There is around 18,000 hectares of post-1989 wilding forests. This is small in the scheme of the infestation of 1.5 million hectares.

- Over time any carbon benefits may become negative as more carbon is used controlling spread due to the carbon footprint of continuous control efforts using fossil fuel, machinery, and human resource.
- As the wilding conifer stand matures the amount of carbon sequestered reaches a point where no more carbon can be sequestered.

No carbon reductions as a result of wilding conifer control have been quantified in the analysis.

9. Conclusion

Wilding conifers are a serious and pressing established pest in New Zealand. They reduce the productivity of primary industries and damage the environmental, social, cultural and landscape values that New Zealand is renowned for.

The benefits of control are clear and greatly outweigh the costs. All control options have a demonstrably higher benefit return than costs. The CBA demonstrates that to do nothing, or to do little, is not an option. Not only will doing nothing fail to achieve the objective of sustainable management, it will result in substantial cost for the country.

The CBA demonstrates that the intermediate option for Phase 2 is sufficient to markedly roll back the area occupied by wilding conifers and 'turn the tide'. The minimum plus scenario will also achieve control and protection (but over a smaller area). To achieve sustainable management will require ongoing investment beyond four years and into further phases.

The benefits of Phase 2 are intergenerational. That is, it is beyond the four year term where most of the benefits of Phase 2 will be seen. This is because wilding conifer control protects vulnerable land into the future. That is, the analysis demonstrates the value of a 'stitch in time'—what we do now has large impacts on benefits achieved in the future. Therefore if the objective is to reach a point where wilding conifers can be sustainably managed using a combination of private landowner action and government support, it is better to act swiftly and decisively now.

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Appendix 1 Methodology notes

Labour impact methodology

- Full Time Equivalent labour for Phase 1 of the Wilding Conifer Control Programme estimated by Ministry for Primary Industries.
- The labour calculation was conducted in accordance with NZ Treasury CBAx guidelines and inputs.
- No policy, monitoring, or central government or local government roles were included as an impact.
- Marginal private household income for contractors was calculated using CBAx income input row 42 [2] of $12,381 (25% of annual income for displacement and opportunity cost impact) marginal to jobseeker support single male less than 24.
- Government revenues per contractor (income tax and ACC levies), applied CBAx assumptions, $2,949.
- Avoided jobseeker support benefit, applied CBAx assumptions, single male less than 24 $9,436.
- Government benefit – for each FTE, a reduction in health and justice sector costs (reduction in police hours by two hours ($88x2) and one emergency visit ($376).

Hydro-electricity impact methodology

- Determine the most significant hydro schemes in New Zealand
  - Use published data set – Existing Generation Fleet as datasource.
  - For each hydro scheme in the dataset listed determine what hydro stations comprise each scheme.

- Sum each hydro station's typical annual generation to determine scheme's total generation.
- Results: Waitaki, Clutha, Manapouri, Waikato, Tongiriro and Waikeremoana account for 90 percent of hydroelectricity generation in New Zealand.

- Apply the resource rent value for water from the National Accounts set from *Statistics New Zealand*. The value of water resources for electricity generation is determined using the System of Environmental-Economic Accounting 2012 – Central Framework (SEEA). This is the United Nations' standard framework for compiling asset accounts of natural resources.
- Sources:
  - Resource rent for hydro water (provided by Statistics New Zealand) http://archive stats govt nz/browse_for_stats/environment/environmental-reporting-series/environmentalindicators/Home/Fresh%20water/value-water-resources-hydroelectric-generation aspx
  - Generation Stations by catchment and annual average generation by station :

    Dataset published on Electricity Market Information website (provided by Electricity Authority), (https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_fleet/Existing)
  - Daily Generation by Station (GWh)
    Report published on Electricity Market Information website (provided by Electricity Authority), (https://www emi ea govt nz/Wholesale/Reports/W_GG_C?_si=v|3)
  - Half hourly electricity prices:

    Datasets published on Electricity Market Information website (provided by Electricity Authority), (https://www emi ea govt nz/Wholesale/Datasets/Final_pricing/Final_prices)

Figure 13 Hydroelectricity generation statistics

	Estimated annual value of hydro resource rent (2018)	Gross annual generation Revenue (2016), $million	Generation (GwH per annum)	Generation % of total NZ hydro
Waitaki	196.4	390.3	7980	32%
Waikato	139.2	276.7	3970	16%
Manapouri	135.4	269.0	5100	20%
Clutha	100.1	198.9	3660	15%
Tongariro	38.7	76.9	1343	5%
Waikaremoana	11.8	23.5	442	2%
Grand Total	**621.6**	**1,235**	**2 2,495**	**90%**

Source: Sapere Research Group

Social and Cultural impacts

An October 2015 report, *Evaluating the (Non-Market) Impacts of Wilding Conifers on Cultural values* (Scion, 2015) found that while cultural values were impacted by wilding conifer spread, people's valuation of the impact was not clear-cut. The opinions about the presence of wilding conifers in the study sites were varied. Most typically, people see the presence of trees as good, but natives are preferred. There is an indication that people do not distinguish between plantation conifers and wilding conifers, for example.

For some respondents, wilding conifers represent the demise of healthy mountains, rivers, and land. The potential spread of wilding conifers creates a sense of loss of wellbeing and inability to provide for future generations. People also recognised that conifers had provided benefits for people, including prevention of erosion and the provision of shelter from the wind. People were most concerned about the spread of wilding conifers in awe-inspiring vistas. These vistas and associated experiences are considered unique to New Zealand. However, in some places where wilding conifers flourish, the lush, forested alpine vistas and deciduous autumnal colours (for instance, of the larches) are also appealing. Respondents also expressed concern about how wilding conifers are controlled, and in particular how the landscape would look after the trees had been killed and the effects of the chemicals used for killing the trees.

Wilding conifers also impact on farming lifestyles and many concerns about the impacts of wilding conifers were enclosed in broader concerns about changing farming cultures. Wilding conifers will impact on people's ability to farm. In some places, productive land use is being balanced with removal of wilding conifers and restoration of more indigenous landscapes. This concept of taking a balanced approach to stewardship of the land was frequently expressed as key to the control of wilding conifers.

Wilding conifers can impact on the way people's identities are shaped through ecosystems and landscapes and the experiences they have in those settings. For example, Māori have whakatauki (proverbs) about their links to their ancestors. In turn, whakatauki are linked to a physical location (environmental space) that provides spiritual or ancestral meaning. The retelling of the whakatauki is a cultural practice which conveys tūrangawaewae (which can be interpreted as a cultural ecosystem benefit) (Carr 2008). Assertions were made in some of the interviews that specific sites of cultural value could not, or even should not, be discussed in isolation from the whole area. This sentiment came through in the Tarawera survey for example, with the whole area being named 3 times as a site of significance:

"I am the river and the river is me". They [people of the Whanganui River] have grown up with that flowing through their veins. There's that deep sense of I am the river and the river is me, and vice versa. It flows from the mountain to the sea and the sea back to the mountain, there's that whole connection …That's what we say about the mountain. We are the mountain, and the mountain is us. That sense of belonging is deep rooted, it's in your DNA. It has to be, it's there. And it gets reinforced, reinforced by catching a fish, by chasing a pig, by seeing a deer. I can't explain it really (Land Manager, pers. comm., June 2015)."

Cultural values are enacted nationally and locally, in specific ways at specific sites, so values take different meanings depending on context. For example the Scion cultural values study identified sites of cultural value and asked respondents to identify the impacts on those sites. The main cultural practices common across the sites impacted by wilding conifers were walking, hunting, cycling, picnicking, swimming, boating, fishing, weddings, remembering family holidays, spiritual connection, holidaying, and camping, creating legacy, and appreciating or curating heritage. The majority of the interviewees preferred the scenario of complete removal of wilding conifers from most of the environmental spaces for access, visual, aesthetic, cultural and natural heritage reasons. The alternative perspective expressed in interviews was largely to do with visual impacts of removal and loss of the seemingly European or Canadian alpine aesthetic.

Key to the challenge of evaluating impacts is recognizing that cultural values are best understood as dynamic, evolving through their specific relationships and contexts. Part of this dynamism is the level of knowledge about wilding conifers as a 'pest tree'. The cultural impact report found that people actively managing wilding conifers were highly concerned about the potential negative impacts on cultural values, but people from the general public demonstrated a level of acceptance for the presence of the trees, even on sites of significance. This indicates that if the control of wilding conifers becomes a topic of national conversation then a national valuation of the impact of wilding spread on cultural values may become more significantly negative.

Perceived negative impacts of wilding conifer incursion in environmental spaces such as camping grounds, picnic spots, roads, walking tracks and lake access points can all be managed. These spaces were commonly noted as the most significant 'use' sites in the Scion cultural values survey. It will be the perceived negative and positive impacts on the aesthetic of the areas that will potentially be more difficult to manage, and will be potentially have the most cultural impact if wilding spread is rapid or becomes uncontrollable.

Appendix 2 Data tables

Figure 14 Current infestation of wilding conifers (productive land highlighted grey)

National total, infestation by landuse	Wilding Conifer Infestation					
	DENSE	INTERMEDIATE	SCATTERED	OUTLIER	TOTAL occupancy	Landuse %
Alpine Grass/Herbfield	574	1,360	8,649	19,285	29,868	2%
Broadleaved Indigenous Hardwoods	1,262	5,948	19,577	29,216	56,003	3%
Built-up Area (settlement)	366	213	600	212	1,392	0%
Deciduous Hardwoods	305	423	1,083	1,099	2,911	0%
Depleted Grassland	1,342	9,020	5,375	26,362	42,099	2%
Estuarine Open Water	-	20	141	333	494	0%
Exotic Forest	12,591	11,070	9,613	17,354	50,628	3%
Fernland	167	429	7,506	6,292	14,394	1%
Flaxland	4	208	186	242	640	0%
Forest - Harvested	1,391	1,291	1,610	2,573	6,865	0%
Gorse and/or Broom	792	1,561	2,886	3,410	8,649	0%
Gravel or Rock	1,011	5,875	25,344	51,001	83,231	5%
Herbaceous Freshwater Vegetation	183	1,215	4,198	8,374	13,969	1%
Herbaceous Saline Vegetation	-	7	216	79	302	0%
High Producing Exotic Grassland	6,388	7,931	25,670	43,095	83,084	5%
Indigenous Forest	3,632	24,193	75,974	163,442	267,241	15%
Lake or Pond	990	1,888	3,842	4,624	11,344	1%
Landslide	50	342	559	1,831	2,782	0%
Low Producing Grassland	7,532	65,162	66,423	211,724	350,841	19%
Manuka and/or Kanuka	3,609	34,972	35,586	59,092	133,258	7%
Matagouri or Grey Scrub	809	3,725	4,885	10,735	20,156	1%
Mixed Exotic Shrubland	221	5,419	6,883	4,221	16,744	1%
Orchard, Vineyard or Other Perennial Crop	9	135	335	205	683	0%
Permanent Snow and Ice	-	-	86	335	421	0%
River	135	225	1,057	1,652	3,068	0%
Sand or Gravel	4	211	904	287	1,407	0%
Short-rotation Cropland	212	59	818	526	1,615	0%
Sub Alpine Shrubland	489	2,899	23,655	30,214	57,256	3%
Surface Mine or Dump	21	20	91	206	337	0%
Tall Tussock Grassland	3,147	83,286	151,050	317,108	554,591	30%
Transport Infrastructure	13	32	69	165	279	0%
Urban Parkland/Open Space	66	75	463	43	648	0%

(blank)	844	2,449	3,786	1,585	8,665	0%
Mangrove	-	37	81	179	296	0%
Grand Total	**48,160**	**271,700**	**489,200**	**1,017,100**	**1,826,160**	**100%**
				Productive total	488,098	27%

Source: Sapere, using data generated by Wildlands Limited applying infestation data from the National Wilding Conifer Infestation database.

Figure 15 Controlled Management Areas, by scenario (shading indicates control)

Control, by scenario	Phase 1	Do Nothing	Minimum Plus	Intermediate	Maximum

Albury					
Alexandra					
Ashley					
Awaroa					
Awatere					
Banks Peninsula					
Barrier Islands					
Branch/Leatham					
Broadlands					
Buller					
Cape Reinga					
Catlins					
Central Hawkes Bay					
Chatham Islands					
Clutha					
Coromandel Mid					
Coromandel North					
Coromandel South					
Craigieburn					
Dargaville					
Dunedin					
Dunstan					
East Coast					
East Otago					
Ernslaw					
Fiordland					
Five Rivers					
Four Peaks					
Foxton					
Glenorchy					
Godley					
Golden Bay					
Grey					
Gwavas					
Hakatere					
Hihitahi					
Hunter Hills					
Hunua					
Hurunui					
Inner Gulf Islands					
Kaikoura					
Kaimanawa					
Kawarau					
Lammermoor					
Lewis					
Lower Clarence					
Lower Wairau					
Luggate					
Mamaku					
Mangonui					
Marokopa					
Mavora					
Mid Clarence					
Mid Dome					
Molesworth					
Mount Richmond					
Mount Taranaki					
Muriwai					
Nelson Lakes					
North Wairarapa					
Northern Eyre					
Northern Tararua					
Ohau					
Orewa/Kawau					
Patea					
Pirongia					
Plains Mid					
Plains North					
Plains South					
Pohangina					
Port Waikato					
Porters					
Pukaki					
Puketoi					
Akatarawa					

Control, by scenario	Phase 1	Do Nothing	Minimum Plus	Intermediate	Maximum
Pureora					
Rainbow					
Rakiura					
Rangitaiki					
Raukumara					
Remarkables					
Rimutaka					
Rotorua Lakes					
Rough Ridge					
Ruahine					
Ruatoria					
Russell					
Shotover					
Sounds Central					
Sounds East					
Sounds West					
South Wairarapa					
Southern Tararua					
Southland Plains					
St Mary/Ida					
Takitimu					
Taupo East					
Taupo West					
Tauranga					
Te Pohue					
Te Urewera\Whirinak					
Tekapo East					
Tekapo West					
Tongariro					
Tuatapere					
Turakina South					
Tutamoe					
Tutira					
Twizel					
Waiau					
Waihopai					
Waihou					
Waikaremoana					
Waimea Moutere					
Waipa					
Waipu					
Wairau Foothills					
Wairoa					
Waitakere Ranges					
Waitaki					
Waitara					
Wakatipu					
Wanaka					
Wangapeka					
Wellington					
Wellsford					
West Otago					
Westlands					
Whanganui Forest					
Whangarei					
Whatatutu					
Wilkin					

Figure 16 Controlled wilding conifers, by scenario

National totals	Intermediate scenario - hectares controlled				Minimum plus scenario - hectares controlled			
Row Labels	DENSE	INTERMEDIATE	SCATTERED	OUTLIER	DENSE	INTERMEDIATE	SCATTERED	OUTLIER
Alpine Grass/Herbfield	574	1,360	8,649	19,285	54	82	2,034	10,889
Broadleaved Indigenous Hardwoods	561	3,906	17,747	27,044	79	652	1,592	2,104
Built-up Area (settlement)	355	188	566	159	44	69	331	59
Deciduous Hardwoods	299	419	1,076	1,064	105	216	397	537
Depleted Grassland	1,338	9,020	5,375	26,362	876	7,811	2,428	20,358
Estuarine Open Water	-	-	34	6	-	-	-	-
Exotic Forest	10,950	9,078	8,030	15,428	4,447	2,638	1,273	1,900
Fernland	139	415	7,227	6,205	45	148	3,350	1,873
Flaxland	4	206	183	239	0	-	41	10
Forest - Harvested	1,283	1,020	1,059	1,891	139	169	39	76
Gorse and/or Broom	683	1,091	2,709	3,050	246	307	1,261	1,474
Gravel or Rock	999	5,864	25,334	50,933	681	3,542	14,997	30,285
Herbaceous Freshwater Vegetation	181	1,142	3,964	8,027	105	350	2,024	6,511
Herbaceous Saline Vegetation	-	-	60	35	-	-	-	-
High Producing Exotic Grassland	6,060	6,874	24,434	38,497	3,664	2,943	9,954	23,496
Indigenous Forest	3,161	23,103	73,553	155,692	946	8,541	14,615	59,771
Lake or Pond	960	1,810	3,807	4,539	613	1,071	2,515	2,432
Landslide	48	341	555	1,828	28	232	419	946
Low Producing Grassland	7,432	64,855	64,048	211,048	5,955	52,067	39,887	113,632
Manuka and/or Kanuka	3,052	31,256	28,116	47,981	1,598	19,128	10,294	21,481
Matagouri or Grey Scrub	802	3,701	4,868	10,728	755	2,896	3,571	6,226

Mixed Exotic Shrubland		5,374	6,787				5,695	
	213			4,183	87	4,564		2,470
Orchard, Vineyard or Other Perennial Crop					9			6
Permanent Snow and Ice	9	124	327	158	-	116	289	-
	-	-				-	-	
			86	335				
River			1,053			99		
	133	220		1,628	85		637	1,144
Sand or Gravel		2		97	-	-	-	-
	1		65					
Short-rotation Cropland	211	57	816			29		
Sub Alpine Shrubland	489	2,899	23,655	522	98		558	276
						1,408		10,858
				30,212	309		16,490	
Surface Mine or Dump						8		
	20	20	85	176	20		36	31
Tall Tussock Grassland	3,147			316,855		59,582		
		83,286	151,050		2,476		108,090	216,839
Transport Infrastructure					7	6		2
	13	30	68	151			27	
Urban Parkland/Open Space				27		36		4
	66	72	454		10		114	
(blank)	-		1,072	56	-	-	-	-
		15						
Mangrove	-	-		25	-	-	-	-
			8					
Grand Total	**43,184**	**257,751**	**466,919**			**168,710**	**242,960**	**535,690**
				984,465	**23,480**			

Source: Sapere, using data generated by Wildlands Limited applying infestation data from the National Wilding Conifer Infestation database.

Note: in the status quo scenario, no wilding conifers are controlled.