METHODS FOR THE PRIORITISATION OF WILDING CONIFER SITES ACROSS NEW ZEALAND

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METHODS FOR THE PRIORITISATION OF WILDING CONIFER SITES ACROSS NEW ZEALAND

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APPENDICES

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1. INTRODUCTION

The Ministry for Primary Industries (MPI) recently led the development of the New Zealand Wilding Conifer Management Strategy 2015-2030 (the strategy). Members of the strategy working group provided a range of perspectives, including the Department of Conservation, Land Information New Zealand, New Zealand Defence Force, regional councils, district councils, Scion, New Zealand Forest Owners Association, Federated Farmers, community groups, and MPI.

One action in the strategy is to prioritise wilding conifer infestations, based on the best information available, to inform allocation of funding and control effort. Various steps and criteria are identified in the strategy, as well as suggested cost sharing for collective wilding conifer management (as a basis for negotiation).

MPI commissioned Wildland Consultants Ltd to prepare, in consultation with stakeholders, a nationally prioritised list of wilding conifer control sites across New Zealand. This report describes the methods that were used to prioritise wilding conifer sites and a regional cost-sharing analysis.

2. PROJECT SCOPE

The project scope was to:

- Further develop and agree on the prioritisation criteria identified in the New Zealand Wilding Conifer Management Strategy.
- Identify and collect the information required on each site in order to apply the prioritisation criteria. This built on the inventory of approximately 550 sites that MPI supplied at the start of the project.
- Review and agree on the proposed management objectives for each site.
- Apply the criteria to all sites and agree on the final prioritised list.
- Determine the cost-share implications for Crown/regional councils/land occupiers based on the prioritisation of sites.
- The approach will need to provide MPI with the ability to review and update the prioritisation exercise on a regular basis.

As noted above, this report only addresses methods developed - for this project - for prioritisation of wilding conifer sites across New Zealand.

3. PROJECT METHODS

3.1 Revision of database

The database supplied by MPI was initially reviewed for completeness and clarity of content. A number of issues were identified relating to standardisation of information, and mixing of attributes which needed to be separated for analysis. The database was therefore 'cleaned' to standardise information and to separate attributes, such as the wilding conifer species present at a site.

Further revision of the database was undertaken using new site attributes obtained from field managers and contractors. This included the proportion of spread occupied by each species at each site (e.g. 80% contorta pine - *Pinus contorta*, 20% Douglas fir - *Pseudotsuga menziesii*), and the separation of the 'sparse spread' attribute into 'sparse-coning' and 'sparse non-coning' spread. Considerable work was undertaken to obtain this new information from site contacts.

3.2 Stakeholder consultation

From October 2015 to January 2016 a number of meetings were held jointly with MPI staff and an operational advisory group that included representatives from the farming industry, regional councils, Department of Conservation, Land Information New Zealand, New Zealand Defence Force, and the New Zealand Forest Owners Association.

Early meetings focussed on identification of the attributes that would be used as a basis for site prioritisation. At these meetings, the need was identified to concentrate initial efforts on sparsely-distributed wilding conifer spread. Consultation group members also provided comments on the structure and wording of a questionnaire sent to wilding conifer experts, and identified experts to which it could be sent. At later meetings, the methodology used for site prioritisation was presented to stakeholders, along with the outcomes of prioritisation in terms of the prioritised sites.

The proposed prioritisation methodology, once developed to an advanced state, was also presented to a technical advisory group including staff from Landcare Research, Scion, LINZ, and Department of Conservation, who provided useful comment.

Regular consultation with MPI also occurred through weekly phone conferences in the final few months of the project.

This consultation was invaluable and made a significant contribution to the outputs of the prioritisation project. It is also hoped that the involvement of regular stakeholder consultation will help to ensure that the prioritisation process and outcomes are accepted by stakeholders.

3.3 Prioritisation

A number of attributes were initially proposed as a basis for prioritisation, including spread risk, degree of likely invasion, impacts on values, levels of existing support, cost, and probability of success. Stakeholder discussion resulted in impacts on values not being included as a prioritisation attribute. Values include environmental, landscape, social, and economic disciplines, for which spatial information at a national scale is often lacking or insufficient, and it is also difficult to rank values across disciplines. Level of support, cost, and probability of success are all related. Level of support influences the cost of a control programme, and these attributes also influence the likelihood of success. In addition, level of support is a categorical rather than a continuous variate, reducing its utility for modelling. Level of support, cost, and probability of success are probably best used as filters to further prioritise sites that have been prioritised on biological attributes, such as spread risk and vulnerability. For these reasons, the prioritisation focussed on the invasiveness of the wilding conifers present, and the vulnerability of the surrounding landscape to wilding conifer invasion. The prioritisation process is described more fully in Section 6 below.

4. WILDING CONIFER SITE DATABASE

4.1 Fields

The 30 fields in the wilding conifer site database supplied by MPI are listed in Appendix 1. A considerable number of new fields were added to the database as part of this project, including a basis for the potential merging of sites that were close together, provision of species-specific categories for all species listed as being present at sites, automated checks to ensure that proportional data have been correctly entered, division of the sparse category into coning and non-coning subcategories, standardised fields for siting, downwind land use, and downwind vegetation, and fields for calculation of cost shares, cost-effectiveness, invasiveness, vulnerability, and risk scores for each site.

4.2 Merging of sites

A number of sites were either located at the same point, or were close together. In particular, information for a large number of relatively small sites was provided in the Queenstown area. As sites were the basis for the assessment of risk and cost-effectiveness, many adjacent sites infested by the same conifer species and with similarly vulnerable surrounding landscapes were merged to reduce ‘spatial duplication’ of risk scores.

4.3 Wilding conifers

Eighteen conifer species are recorded in the wilding conifer site database (Table 1). Of these, contorta pine is present at the most sites, followed by Douglas fir and radiata pine (*Pinus radiata*), which are all widely distributed. *Pinus nigra* and larch (*Larix decidua*) are present at a moderate number of sites, while all other conifer species occur relatively infrequently at sites.

Non-coniferous tree species recorded in the database include rowan (*Sorbus aucuparia*; four sites), silver birch (*Betula pendula*; one site), Australian beech (one site), eucalyptus (*Eucalyptus* sp.; three sites), willow (*Salix* sp.; five sites), hawthorn (*Crataegus monogyna*; one site), and poplar (*Populus* sp.; two sites). Non-coniferous tree species are outside the scope of this prioritisation project, but were separated out in the amended site database.

Table 1: Entries for wilding conifer species recorded in the wilding conifer site database.

Species/Taxon	Common Name	Number of Sites
Araucaria heterophylla	Norfolk Island pine	1
Chamaecyparis lawsoniana	Lawson's cypress	1
Cryptomeria japonica	Japanese cedar	3
Cupressus macrocarpa	Macrocarpa	4
Larix decidua	Larch	133
Larix kaempferi	Japanese larch	4
Picea sp.	Spruce	2
Pinus contorta	Contorta, lodgepole pine	255
Pinus ellioti		1
Pinus monticola	Western white pine	3
Pinus mugo	Mountain pine	25
Pinus muricata	Bishop pine	12
Pinus nigra	Black pine, Corsican pine	134
Pinus patula	Patula pine	3
Pinus pinaster	Maritime pine	35
Pinus ponderosa	Ponderosa pine	31
Pinus radiata	Radiata pine	215
Pinus sp. / Pine		6
Pinus sylvestris	Scots pine	57
Pinus strobus	Strobus pine	5
Pseudotsuga menziesii	Douglas fir	252
Unknown		3

5. EXISTING PRIORITISATION SCHEMES

An existing wilding conifer spread risk calculator was developed by Ledgard (2012). This calculator (DSS1) is site-based and weights five criteria - spreading vigour, palatablility, siting, downwind grazing pressure, and downwind land cover - using a 0-4 scale. Key elements of this scoring system are spreading vigour, which is property of individual species, and downwind land use, which addresses the vulnerability of land to invasion by wilding conifers. These two elements are discussed further below.

5.1 Spreading vigour

Spreading vigour may be thought of as the rate at which an invading conifer forms closed stands in suitable habitat that was previously unoccupied by wilding conifers.

Spreading vigour relates to early reproduction, heavy seed production, and habitat breadth. Thus contorta pine, which reaches significant coning on eight-year-old trees, produces abundant, very light seed, and can occupy a range of habitats, has the most significant spreading vigour of all wilding conifers in New Zealand (Ledgard 2012). This is demonstrated by contorta pine being listed at more (255) wilding conifer control sites than any other species, despite being classified as an Unwanted Organism and being illegal to plant it. Douglas fir and Corsican pine (*Pinus nigra* subsp. *laricio*) also have high spreading vigour and are present at many sites.

Spreading vigour of wilding conifer species present in New Zealand was originally included by Ledgard & Langer (1999) in guidelines for minimising the risk of unwanted spread, and has been subsequently used as the basis for spreading vigour in DSS1 (Ledgard 2012; Table 2).

Table 2: Spreading vigour of wilding conifers (from Ledgard 2012).

Weighting	Species
0	Redwoods, Leyland cypresses (*Chamaecyparis* sp.), cedars and spruces (very low risk - no need to proceed further).
1	Radiata (*Pinus radiata*) and ponderosa (*P. ponderosa*) pine, Lawson's cypress (*Chamaecyparis. lawsoniana*).
2	Muricata (*Pinus muricata*) and maritime (*P. pinaster*) pine and larches (*Larix* spp.).
3	Corsican (*Pinus nigra*) and mountain/dwarf mountain (*P. uncinata/mugo*) pine.
4	Douglas-fir (*Pseudotsuga menziesii*), Scots pine (*Pomis sylvestris*).
5	Lodgepole/contorta pine (*Pinus contorta*).

5.2 Downwind land use

Ledgard (2012) used two aspects of downwind land use: grazing pressure and land cover. In practice, these two aspects are entwined, with high-intensity browse pressure in high producing pasture and cropland, and low to moderate browse pressure on most other vegetated cover classes. Also, while browse pressure can be assessed locally at a site, it isn't possible to map browse pressure nationally. For these reasons, land cover alone is the most informative attribute as an index of the susceptibility of downwind land to wilding conifer invasion and spread.

Ledgard (2012) referred to five classes of land cover (Table 3). These classes cover the general habitats in which wilding conifer spread occurs, but the cover classes are not mapped and do not always relate to land cover database (LCDB) categories. Thus they are difficult to utilise in spatial models and prioritisation frameworks.

Table 3: Landcover classes defined by Ledgard (2012).

Priority	
0	Developed pasture, rank grass, plantation forest (no gaps).
1	Native forest, shrubland/tussock/grassland with a continuous and heavy vegetation cover.
2	Forest/shrubland/tussock/grassland with few gaps.
3	Open forest and/or scattered patches of dense shrubland/tussock/grassland with many gaps.
4	Open slips/rockland and/or light, low-stature shrubland/tussock/grassland.

McNeill (2008) modelled wilding conifer spread risk in the Canterbury Region, using digital elevation data, LCDB2, and a wilding conifer database. Wind was modelled simply, assuming one direction of wind and simplified rules between wind interaction with terrain features. Land cover classes from LCDB2 were classified into the four Ledgard (2008) categories (Table 4), although there were obvious difficulties in doing so given that the Ledgard (2008) framework placed the same cover classes in different categories depending on condition. Other problems are that the placement of cover classes in some categories does not always have an ecological basis. For example, relatively invasible mixed shrubland is grouped into a relatively low-risk category, while broadleaved indigenous hardwoods, a closed canopy forest category that is not very susceptible to wilding conifer invasion, is grouped into a moderate risk category. Furthermore, flaxland is given a moderately high risk despite being a wetland type that wilding conifers would not easily invade.

Table 4: Amalgamation of LCDB2 cover classes into Ledgard (2008) invasion vulnerability classes (from McNeill 2008). Invasion risk increases down the table.

Ledgard (2008) Classes	Matching LCDB2 Classes (McNeill 2008)
Developed pasture, rank grass, closed canopy forest/scrub, tussock grassland with a continuous, vigorous permanent vegetation cover	Short rotation cropland Orchard, vineyard, or other perennial crop Herbaceous freshwater vegetation Herbaceous saline vegetation High producing exotic grassland Pine forest open canopy Pine forest closed canopy Afforestation not imaged Afforestation imaged Forest harvested Minor shelterbelts Major shelterbelts Other exotic forest Deciduous hardwoods Indigenous forest Mangrove Mixed exotic shrubland
Open forest, shrub, tussock, grassland with mostly dense vegetation cover	Gorse and/or broom Mānuka and/or kānuka Matagouri Broadleaved indigenous hardwoods
Shrubland, tussock, grassland with a moderate cover	Flaxland Fernland Low producing grassland Grey scrub Tall tussock grassland
Open slips/rockland, shrubland/tussock/grassland with a light vegetation cover	Alpine grass/herbfield Depleted grassland Subalpine shrubland

6. A NEW WILDING CONIFER PRIORITISATION SCHEME

6.1 Requirement for a new approach

While the outputs of the spreading vigour assessment of Ledgard & Langer (1999) are intuitive, a consensus-based and objective alternative framework for the assessment of spreading vigour was sought, with continuous variation (rather than categories), and which could be easily verified and updated. In addition, downwind land use needs to be mappable if it is to be incorporated into a national prioritisation framework. Due these issues, a new approach to prioritising wilding conifer sites was developed. A key to this approach was obtaining expert consensus on attributes of wilding conifer spread, through the use of a questionnaire.

6.2 Questionnaire

The questionnaire asked expert respondents to evaluate the invasiveness of the ten wilding conifer species that are responsible for most wilding spread in New Zealand (c.f. Froude 2011), within different land cover categories. Other conifer species known to be associated with local spread (Webb *et al.* 1988), such as macrocarpa (*Cupressus macrocarpa*), white mountain pine (*Pinus monticola*), and patula pine (*P. patula*), were also evaluated by some experts.

For national prioritisation, the national scale mapping of LCDB cover classes makes it the most suitable tool for defining land uses that vary in susceptibility to wilding conifer spread. Experts were therefore asked to rank the invasiveness of each wilding conifer species against 18 potentially-invasible land cover categories of LCDB4 (Table 5). Land cover categories assessed as not being invasible by wilding conifers (e.g. wetlands, lakes, intensively-used land, permanent snow and ice) were excluded from the questionnaire (Table 5).

Table 5: Land cover classes included and excluded from the questionnaire.

Land Cover Classes (LCDB4)	
Included in Questionnaire	**Excluded from Questionnaire**
Alpine Grass Herbfield	Dune Shrubland (Chatham Islands)
Broadleaved Hardwoods	Estuarine open water
Deciduous Hardwoods	Flaxland
Depleted Grass	Herbaceous freshwater vegetation
Exotic Forest	Herbaceous saline vegetation
Fernland	High producing exotic grassland
Forest - Harvested	Lake or pond
Gorse and Broom	Mangrove
Gravel or Rock	Orchard, vineyard, or other perennial crop
Indigenous Forest	Peat shrubland (Chatham Island)
Landslide	Permanent snow and ice
Low Producing Grass	River
Manuka and Kanuka	Sand or gravel
Matagouri or Grey Scrub	Short-rotation cropland
Mixed Exotic Shrub	Surface mine or dump
Sand or Gravel	Transport infrastructure
Sub Alpine Shrubland	Urban parkland/open space
Tall Tussock Grass	

The questionnaire included a matrix where the invasiveness of each wilding conifer species was assigned a 0-100 score by respondents in each invasible LCDB4 cover class, with zero corresponding to no invasive capability, and 100 corresponding to the highest invasive capability (Table 6). Co-variates that respondents were asked to complete included years of experience, regions where experience was gained, and predominant role (classified as scientist, manager, or operational).

A total of 26 responses to questionnaires were received, mostly from operational staff and managers, but with six people with a scientific background also responding (Appendix 2). Contorta pine and radiata pine were ranked by all respondents, and Douglas fir by all but one. Black pine (*Pinus nigra*), Scots pine (*P. sylvestris*), ponderosa pine (*P. ponderosa*), mountain pine (*P. mugo*), and European larch (*Larix decidua*) were ranked by 13-17 respondents. Relatively few respondents were familiar with wilding spread of maritime pine (*Pinus pinaste*r; five responses), bishop pine (*P. muricata*; three responses), macrocarpa (two responses), spruce (*Picea abies*; two responses), or white mountain pine (one response).

Analysis of the questionnaire data provided a transparent, expert consensus-based rating of the spreading vigour of each wilding conifer species or group of species, in different land cover categories, which was used to model spread risk. Wilding conifer species were analysed separately using linear mixed-effects models, with the respondents being a random effect. The predictive strength of land cover type was assessed against the identity of experts. For most species, land cover type was the strongest predictor. The models were then used to predict relative risk scores for each species in each land cover type.

The outcome was a points-based system where higher points indicate greater spread risk or susceptibility to invasion. Previous assessments of spread risk have not been subject to expert consensus, and are generalised across all habitats.

Contorta pine (mean modelled ranking of 41) and Douglas fir (37) were ranked as having very high invasiveness, while Scots pine (25) and black pine (24) had high invasiveness (Table 6). European larch (18) and white mountain pine (16) were ranked as having moderate invasiveness. Ponderosa pine, radiata pine, mountain pine, maritime pine, spruce, bishop pine, and macrocarpa were assessed as having relatively low invasiveness (9-13). These mean modelled rankings apply across all habitats

Tall tussock grassland (mean modelled vulnerability of 36), depleted grassland (33) and low-producing exotic grassland (32) were assessed as being very highly vulnerable to wilding conifer invasion (Table 6), while subalpine shrubland, landslide, mānuka or kānuka, fernland, and gravel or rock were assessed as having high vulnerability (mean modelled vulnerability of 21-29). Sand or gravel, alpine grass/herbfield, gorse and broom, matagouri or grey scrub, mixed exotic shrubland, and harvested forest were assessed as having moderate vulnerability (12-19), while forest cover classes (indigenous forest, exotic forest, broadleaved hardwoods, and deciduous hardwoods) were assessed as having relatively low vulnerability (3-7) to invasion by exotic conifers. These modelled rankings apply across all wilding conifer species.

Table 6: Mean modelled expert scores of wilding conifer invasiveness within land cover (LCDB4) categories.

LCDB4 Category	*Pinus contorta*	*Pinus monticola*	*Pinus mugo*	*Pinus muricata*	*Pinus nigra*	*Pinus pinaster*	*Pinus radiata*	*Pinus ponderosa*	*Pinus sylvestris*	*Psuedotsuga menziesii*	*Cupressus macrocarpa*	*Larix decidua*	Means (LCDB)
Alpine Grass Herbfield	64	0	37	1	27	7	8	7	36	45	0	17	**19**
Broadleaved Hardwoods	7	8	1	4	5	11	6	4	0	17	0	3	**5**
Deciduous Hardwoods	7	3	1	1	4	3	3	2	4	12	0	3	**3**
Depleted Grass	82	20	24	11	6	15	27	23	60	61	10	45	**31**
Exotic Forest	9	0	1	1	4	3	6	2	4	11	0	3	**3**
Fernland	22	35	2	16	12	8	8	4	1	27	50	8	**19**
Forest – Harvested	27	30	1	9	10	5	38	2	7	39	0	4	**13**
Gorse and Broom	29	30	3	9	22	21	16	11	3	29	1	16	**15**
Gravel or Rock	57	15	31	6	27	11	12	5	23	37	0	22	**19**
Indigenous Forest	10	5	1	2	5	8	4	2	4	37	5	4	**7**
Landslide	51	55	31	32	31	29	17	4	30	46	0	21	**27**
Low Producing Grassland	75	15	24	9	54	14	22	26	52	59	5	40	**31**
Manuka and Kanuka	43	30	4	20	20	26	15	14	13	52	10	8	**20**
Matagouri or Grey Scrub	47	5	10	2	31	5	9	15	33	46	0	30	**18**
Mixed Exotic Shrub	28	5	3	2	23	6	12	15	19	36	30	20	**18**
Sand or Gravel	39	15	2	6	25	9	12	3	17	26	0	10	**12**
Sub Alpine Shrubland	70	0	34	1	36	9	8	11	53	51	5	30	**24**
Tall Tussock Grassland	73	10	35	6	54	13	14	24	56	61	50	38	**37**
Means (conifers)	**41**	**16**	**14**	**8**	**22**	**11**	**13**	**10**	**23**	**38**	**9**	**18**	

6.3 Invasiveness scores

The invasiveness score of each wilding conifer species at a site was calculated by multiplying the proportion of spread occupied by a wilding conifer species at a site by the modelled invasiveness rating of the species (Table 7). Proportion of spread for different species at a site was provided in the site database, and comprises 'best estimate' values contributed by site contacts, rather than counted or measured data. Proportion of spread was also integrated across all classes of wilding tree age and density at a site, including both coning and currently non-coning trees, and could change over time at a site. However, this is useful information with which to generate short term priorities based on current site information.

Where just one wilding conifer species was present at a site, the species invasiveness score is the same as the site invasiveness score (Table 7). Where more than one wilding conifer species was present at a site, the sum of individual species invasiveness scores was used to derive the site invasiveness score (Table 7).

Table 7: A selection of wilding conifer invasiveness scores for different sites.

Site	Species	Proportion (%)	Species Scores	Site Invasiveness Score (as fraction)
Rangipo North	Contorta pine	100	100 x 41 = 4,100	**0.41**
Mid Dome	Contorta pine Mountain pine Douglas fir	97.5 2 0.5	97.5 x 41 = 3,998 2 x 14 = 28 0.5 x 38 = 19	3,998 + 0.0028 + 0.0019 = **0.40**
Roaring Meg	Douglas fir	100	100 x 38 = 3,800	**0.38**
Cecil Peak	Douglas fir Black pine Scots pine Larch	65 15 15 5	65 x 38 = 2,405 15 x 22 = 330 15 x 23 = 345 5 x 18 = 90	0.2405 + 0.033 + 0.0345 + 0.009 = **0.32**
Hawkdun Range	Contorta pine Black pine Radiata pine Larch Douglas fir	10 60 10 10 10	10 x 41 = 410 60 x 22 = 1,320 10 x 13 = 130 10 x 18 =180 10 x 38 = 380	0.041 + 0.132 + 0.013 + 0.018 +0.038 = **0.20**
Rangitoto Island	Radiata pine Maritime pine	97 3	97 x 13 = 1,261 3 x 11 = 33	0.1261 + 0.0033 = **0.13**

Table 7 shows that among the sites used as examples, the Rangipo North site has the highest invasiveness score, because contorta pine, the most invasive species, is the only species present. The Mid Dome site is not far behind as wilding conifer spread there is dominated by contorta pine. The Roaring Meg site has slightly lower invasiveness as Douglas fir, the second-most invasive species, is dominant at that site. Sites such as Cecil Peak and the Hawkdun Range, where Douglas fir and black pine are common wilding conifers among others, score relatively highly, whereas the Rangitoto Island site, where the moderately invasive radiata pine and maritime pine are present, has a relatively low invasiveness score.

6.4 Vulnerability scores

Vulnerability of land around each site was evaluated for areas within 20 kilometres of the site coordinates supplied. The area of each LCDB cover class within these areas was first divided by the site buffer area, and then multiplied by its wilding vulnerability score, expressed as a fraction (Table 8). The products of area × vulnerability risk for each cover class were summed to give an overall value for the site (Table 8), which was also expressed as a fraction.

Table 8 shows that the Roaring Meg site has higher vulnerability than the Rangipo North and Mid Dome sites. At Roaring Meg, large areas of readily-invasible low producing exotic grassland and tall tussock grassland are mostly responsible for the high vulnerability score. At the Rangipo North site, areas of tall tussock grassland, subalpine shrubland, and gravel or rock contribute mostly to the vulnerability score. At Mid Dome, areas of low producing exotic grassland and tall tussock grassland contribute most to the vulnerability score, but are not as extensive as at the other two sites. Mid Dome's lower vulnerability at the 20 kilometre buffer radius is because there are large amounts of high producing exotic grassland and indigenous forest within the buffer area, which have low vulnerability to wilding conifer invasion.

Table 8: Site vulnerability scores for the Roaring Meg, Rangipo North, and Mid Dome sites, based on a 20 km buffer radius.

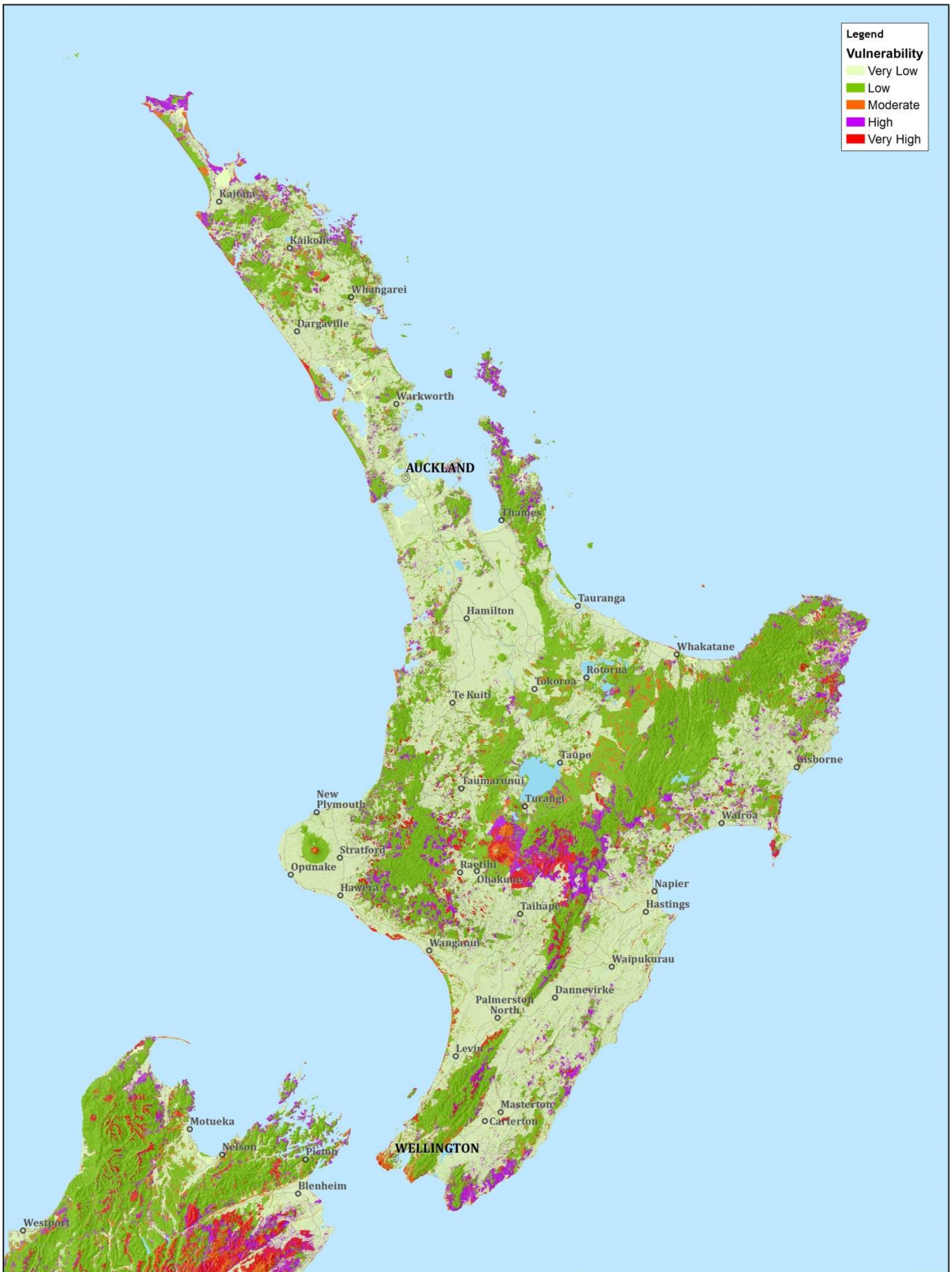
Site	Land Cover Type	Cover Type Area/ Site Buffer Area	Vulnerability (from questionnaire)	Risk Score (Cover Type Area Fraction × Vulnerability)
Roaring Meg	Deciduous hardwoods	0.007	0.03	0.0002
	Depleted grassland	0.032	0.31	0.0099
	Exotic forest	0.003	0.03	0.0001
	Fernland	0.001	0.19	0.0002
	Forest harvested	0.001	0.13	0.0001
	Gorse and broom	0.001	0.15	0.0002
	Gravel or rock	0.010	0.19	0.0019
	Indigenous Forest	0.001	0.07	0.0001
	Landslide	0.001	0.27	0.0003
	Low producing exotic grassland	0.389	0.31	0.1206
	Mānuka and kānuka	0.009	0.20	0.0018
	Matagouri or grey scrub	0.007	0.18	0.0013
	Mixed exotic shrubland	0.087	0.18	0.0157
	Subalpine shrubland	0.001	0.24	0.0002
	Tall tussock grassland	0.358	0.37	0.1325
Overall site vulnerability score (sum of individual risk scores)				**0.29**
Rangipo North	Alpine grassland/herbfield	0.036	0.19	0.0068
	Broadleaved indigenous hardwoods	0.003	0.05	0.0002
	Depleted grassland	0.032	0.31	0.0099
	Exotic forest	0.055	0.03	0.0017
	Fernland	0.001	0.19	0.0002
	Forest harvested	0.017	0.13	0.0022
	Gorse and broom	0.001	0.15	0.0002
	Gravel or rock	0.134	0.19	0.0255
	Indigenous Forest	0.227	0.07	0.0159
	Low producing exotic grassland	0.007	0.31	0.0022

Site	Land Cover Type	Cover Type Area/ Site Buffer Area	Vulnerability (from questionnaire)	Risk Score (Cover Type Area Fraction × Vulnerability)
	Mānuka and kānuka	0.076	0.20	0.0152
	Matagouri or grey scrub	0.001	0.18	0.0002
	Mixed exotic shrubland	0.003	0.18	0.0005
	Subalpine shrubland	0.198	0.24	0.0475
	Tall tussock grassland	0.180	0.37	0.0667
Overall site vulnerability score (sum of individual risk scores)				**0.19**
Mid Dome	Alpine grassland/herbfield	0.001	0.19	0.0002
	Broadleaved indigenous hardwoods	0.003	0.05	0.0002
	Deciduous hardwoods	0.007	0.03	0.0002
	Exotic forest	0.023	0.03	0.0007
	Fernland	0.011	0.19	0.0021
	Forest harvested	0.003	0.13	0.0004
	Gorse and broom	0.006	0.15	0.0009
	Gravel or rock	0.025	0.19	0.0048
	Indigenous Forest	0.127	0.07	0.0089
	Landslide	0.001	0.27	0.0001
	Low producing exotic grassland	0.226	0.31	0.0701
	Mānuka and kānuka	0.029	0.20	0.0058
	Matagouri or grey scrub	0.007	0.18	0.0013
	Mixed exotic shrubland	0.009	0.18	0.0016
	Subalpine shrubland	0.003	0.24	0.0007
	Tall tussock grassland	0.163	0.37	0.0603
Overall site vulnerability score (sum of individual risk scores)				**0.16**

6.5 National scale vulnerability

Vulnerability scores for LCDB cover types can be used to map vulnerability nationally (Figures 1a and 1b).

On this basis, 4.1 million hectares of mainland New Zealand has very high vulnerability to wilding conifer invasion, and a further 2.9 million hectares has high vulnerability (Table 9). Across all categories, 16.8 million hectares of land has some degree of vulnerability to wilding conifer invasion.



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Report: R3754
Client: MPI
Ref: 04 0330
Path: E:\gis\WildingPine\mxd\
File: WildingPine_Vulnerability_NI_V2.mxd

Figure 1a. Vulnerability of North Island cover to wilding conifer invasion

0 100 200 km

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Scale: 1:2,500,000
Date: 16/02/2016
Cartographer:
Format: A3

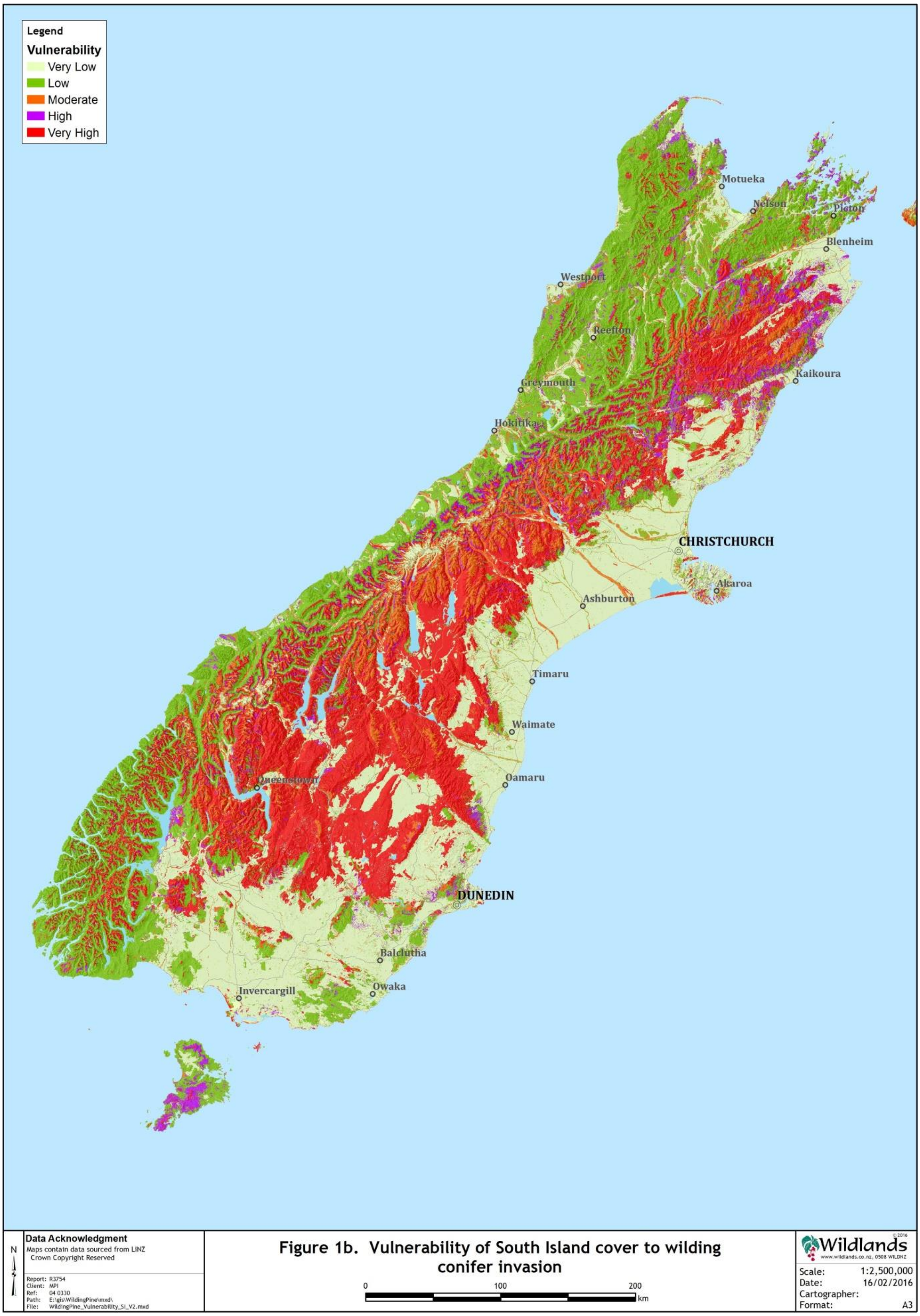

Figure 1b. Vulnerability of South Island cover to wilding conifer invasion

Table 9: Extent of vulnerable land cover on a national basis.

Land Cover Type	Vulnerability Scores (from Questionnaire)	Vulnerability Category	Area Occupied (1,000 ha)
Alpine grassland/herbfield	19	Moderate	229
Broadleaved indigenous hardwoods	5	Low	656
Deciduous hardwoods	3	Low	96
Depleted grassland	31	Very High	173
Exotic forest	3	Low	1,823
Fernland	19	Moderate	72
Forest harvested	13	Moderate	222
Gorse and broom	15	Moderate	205
Gravel or rock	19	Moderate	873
Indigenous Forest	7	Low	6,308
Landslide	27	High	22
Low producing exotic grassland	31	Very High	1,606
Mānuka and kānuka	20	High	1,173
Matagouri or grey scrub	18	Moderate	112
Mixed exotic shrubland	18	Moderate	50
Sand or gravel	12	Moderate	44
Subalpine shrubland	24	High	433
Tall tussock grassland	37	Very High	2,337
Total Area			**16,797**

7. LIMITATIONS AND ASSUMPTIONS

A number of limitations and assumptions have affected this prioritisation project, as discussed below.

7.1 Data limitations

As much of the input data came from a spreadsheet compiled from multiple sources, data in the spreadsheet were not easily verifiable, and an assumption was generally made that all supplied data were correct at time the data was supplied. What may have changed, is that the data may no longer be up-to-date due to ongoing management of sites since information was contributed to the database.

7.2 Site location information

In some cases, GPS coordinates were inserted by Wildlands staff in instances where no GPS coordinates were provided, and where the site location was obvious or verifiable from other sources. GPS coordinates that denote site locations influence the orientation of the buffer that was used to determine site vulnerability, but this would mostly affect outlying land covers due to the large buffer size used. For large sites, a point location and buffer may not adequately represent the variation present across the site.

7.3 Lack of data

Prioritisation of sites was hampered by data missing for many sites. These were gradually whittled down through correspondence with site contacts, but some data were not obtained in time for analysis. This includes a number of sites for which no information was provided on the wilding conifer species present. Similarly, where no GPS coordinates were supplied or could be estimated, it was not possible to assess land cover types in buffer areas. These sites where species or site location information was missing consequently had risk scores of zero and should be treated as not assessed.

7.4 Infestation size

Infestation size was not taken into account when generating the risk scores as, in the absence of a nationally-consistent standard for reporting the extent and density of wilding conifer spread, the data supplied is likely to vary considerably in quality. Also, the extent data provided is at the level of the affected area, and does not provide information on the distribution or density of individual species.

7.5 Delineation of sites

A large number of sites are in the database, but sites were delineated by the site contacts who provided the information, thus there was no standard way in which this was done. Some contacts have split large sites into many smaller ones, while others have combined several smaller sites into large sites. The large number of sites in the Queenstown area is notable, where detailed planning for wilding conifer control has resulted in the demarcation of numerous, relatively small management units, whereas in other cases elsewhere in New Zealand, very large sites have been listed as single entities up to 55,000 ha in extent. The size of a site has an influence on the costs of wilding conifer control.

7.6 Site buffers

Circular site buffers were used in the land vulnerability analyses, and these took no account of predominant wind directions or topographic features that would influence wilding conifer spread. As such, the vulnerability of the surrounding landscape may have been over-estimated at some sites.

7.7 Values affected

Importantly, this prioritisation exercise does not address the status or kinds of values that are potentially affected by wilding conifer spread. It is assumed that some kind of value - whether economic, landscape, or conservation - would be affected by all instances of wilding conifer spread, but the degree of this is not known.

8. MANAGEMENT

8.1 Operational management priorities

At priority sites, the overriding priority of wilding conifer management should be to reduce the extent of the area that has been invaded by wilding conifers. This can be done most easily by controlling sparsely-distributed wilding conifers, especially if they have not reached coning stage, and preventing them from forming more dense stands. As the area infested by wilding conifers shrinks, more resources can then be devoted to controlling the sources of wilding spread. Sources that are associated with the greatest spread risk should be controlled first. Isolated sites should also be given higher priority.

Regional prioritisation and prioritisation within management areas can be implemented in the same way. It may be appropriate for some regions to consider the eradication of sources of wilding spread at an earlier stage than others, depending on the extent of sparsely-distributed wilding trees in each region.

For a given amount of funding resource, funding could be allocated to three primary work streams:

- Sites with large areas of sparse non-coning high spread risk species. Allocate a significant portion of overall funding to these sites. Control of these areas will significantly reduce the total area infested, and after control these sites can move to a surveillance framework with handback to the land manager.
- The middle ground. Sites with sparse but coning high risk species over large areas. Allocate a significant proportion of the remaining resource to these areas. Control will also significantly reduce the total area infested. After initial control, conifer regeneration will require further control before the regenerating individuals form cones.
- Sites with mature wilding conifers in all spread risk categories that are sources of significant wilding spread and have large invasible areas. Allocate the remaining resource to these areas, with priority given to demonstrated take-off sites. Control of these areas will significantly reduce the degree of further wilding spread.

As the first two work streams are dealt with, proportionally more resource can be devoted to the third.

Sites with mature wilding conifers that are sources of significant spread can be prioritised according to spread risk, take-off sites, and cost-effectiveness. Cost-effectiveness can be calculated as the area of trees controlled divided by the cost of control. Where a number of sites are associated with high spread risk, further prioritisation can be made by first undertaking control at those that contain known take-off sites for wilding conifer spread.

8.2 Management objectives

Management objectives specified in the New Zealand Wilding Conifer Strategy (Table 10) are somewhat problematic. For example the objectives have a degree of overlap, with 'containment' featuring in three of the four categories. In addition, the criteria are not consistent between objectives, and some criteria are vague and open to different interpretations.

Table 10: Management objectives provided in the New Zealand Wilding Conifer Management Strategy 2015-2030.

Objective	Criteria
Exclusion	Zero density, high value of land's current state, cost-effective to exclude, risk of invasion.
Eradication/ Containment	Ability to remove all individuals, low-risk of reinvasion, ability to recover site to desired outcome, an area which benefits.
Progressive containment	Defendable boundaries, feasible to remove sources or stop further spread, long term funding for knockdown and ongoing maintenance.
Containment/ Sustained control	Integrated pest management outcomes, externality impacts, widely distributed, long term funding commitment, occupies almost all suitable habitat.

Revised terminology for objectives, and five criteria that can be used to determine which objective is most appropriate for a site are provided in Table 11. As there is no consistent national-scale information on the values affected, and reinvasion risk and restoration potential depend on site context, determination of objectives for sites is best done at a local or regional basis when the above information becomes available.

Table 11: Management objectives, criteria, and actions suggested for wilding conifer management in New Zealand.

Objective	Criteria					Actions	
	Density	Site Values	Vulnerability of Surroundings	Restoration Potential	Reinvasion Risk	Remove Sources	Proposed Methods
Exclusion	Zero	High	High	Not required	Low	Yes	Surveillance and follow-up.
Eradication	Low-Mod	High	High	High	Low	Yes	Knockdown and intensive follow-up.
Progressive control	Mod-High	Mod	Mod-High	Mod-High	Moderate	Yes, over time	Knockdown and ongoing control.
Containment	High	Low	Mod-High	Low	High	No	Boundary control until resources allow to move to a higher category.

9. COST SHARING

For the purposes of determining cost sharing according to the framework in Appendix 3 of the New Zealand Wilding Conifer Strategy, two major assumptions have been made:

- GPS coordinates supplied in the site database can be applied to accurately determine ownership of the site.
- All of the sites are legacy (post-RMA 1991) plantings and wildings.

Ownership status of sites was determined by assessing all conservation land and pastoral leases as public land, and assuming that the remainder is private land. This is not likely to be a wholly accurate split, but for the wild areas in which wilding conifers are present, should be sufficiently accurate. More problematic is that in practice, many sites are likely to cover a mix of public and private land, and some sites are likely to include wildings sourced from post-RMA plantings. For these reasons, the cost sharing calculated in this section should be viewed as 'ballpark costs', with more accurate cost share calculations done when better information was available.

As discussed above, the potential costs of wilding control at each site were obtained from two estimates: estimates of five-year control costs provided by site contacts and area-based control costs. Cost shares were determined for both cost estimates.

The cost-sharing methodology was taken from Appendix 3 of the New Zealand Wilding Conifer Strategy. It was assumed that all sites were affected by legacy plantings. This resulted in two sets of cost shares divided between site landholders, central government, regional government, and adjacent landholders. Cost shares for regional government are listed in Table 12.

Table 12: Regional government cost sharing for control based on two cost scenarios - estimates of five year control costs provided by site contacts and area-based control costs - and the control costs for all sites

Region	Cost Share ($)	
	Costs Estimated by Contacts	**Costs Estimated per Area**
Northland	77,200	179,463
Auckland	14,000	6,900
Waikato	621,175	1,480,378
Bay of Plenty	780,700	920,787
Hawkes Bay	2,638,200	422,098
Gisborne	No data	12,523
Chatham Island	11,200	12
Taranaki	No sites	No sites
Horizons	624,243	2,458,966
Wellington	94,900	105,348
Tasman	805,292	1,050,529
Nelson	145,000	83,910
Marlborough	3,673,278	18,831,769
Canterbury	4,781,257	27,800,400
Otago	2,871,990	6,491,515
Southland	2,458,000	628,246
West Coast	32,000	30,930
TOTALS	**19,662,435**	**64,240,714**

Figures in Table 12 show that the wilding conifer problem, based on relative costs, is predominantly associated with six regions: Hawkes Bay, Horizons, Marlborough, Canterbury, Otago, and Southland. Three other regions also incur significant costs: Waikato, Bay of Plenty, and Tasman.

Notably, the area-based costs are significantly greater (*c.*$64M) than those estimated by site contacts (*c.*$20M). Possibly this is due to control of sparsely-distributed conifers being cheaper than $15 per ha for very sparse but extensive infestations in Marlborough, Canterbury, and Otago.

When estimated areas of dense and sparse wilding conifer spread are summed for each region, the reasons for the cost differences in Table 12 become clear. The six regions that comprise the bulk of the control costs are generally those that have large amounts of sparse and dense wilding conifer spread. Southland is something of an exception, in that it has a relatively low amount of dense spread, and a moderate amount of sparse spread (Table 13). What Southland does have, is a significant infestation of contorta pine, the most invasive species, at Mid Dome, where control costs are high.

Table 13: Estimated areas of dense and sparse wilding conifer spread within Regional Council boundaries.

Island	Council Region	Estimated Area of Wilding Conifer Spread (ha)	
		Dense Spread	**Sparse Spread**
North Island	Auckland	0	2,550
	Bay of Plenty	1,923	36,949
	Chatham Island	0	4
	Gisborne	20	1,505
	Horizons	4,484	112,324
	Northland	447	221
	Waikato	2,192	116,836
	Wellington	180	10,828
	Hawkes Bay	6,201	193,332
North Is Total		**15,447**	**474,549**
South Island	Canterbury	53,095	652,057
	Marlborough	41,399	355,258
	Nelson	0	10
	Otago	11,685	283,961
	Southland	755	41,433
	Tasman	1,807	85,859
	West Coast	50	300
South Is Total		**108,792**	**1,418,878**
Grand Total		**124,239**	**1,893,427**

10. CONCLUSION

A new, expert consensus-based wilding conifer control site prioritisation framework has been developed, incorporating the invasiveness of wilding conifer species, and the vulnerability of different land covers. A key advance in this framework is national mapping of the vulnerability of different land cover types, which shows that much of the eastern South Island is highly vulnerable to wilding conifer invasion. The framework is also transparent and has been built on the consensus of experts involved in wilding conifer management. Cost and cost-effectiveness are not taken into account in the framework, and are best used as filters to select from a list of sites that are prioritised according to invasiveness and vulnerability. Values are not incorporated into the framework but this could easily be done if values were to be mapped nationally.

ACKNOWLEDGMENTS

Adrian Monks, Catriona McLeod, Larry Burrows, and Andrew Gormley (all Landcare Research) provided very helpful discussion on priority-setting frameworks and on wilding conifer issues in general. Peter Raal and Keith Briden (Department of Conservation) assisted with sending out questionnaires to wilding conifer experts. The experts who responded to the questionnaire are deeply thanked for their considered responses. Members of the Operational and Technical consultation groups are thanked for feedback and advice. Numerous contact people are thanked for providing both the original site information and additional information that was critical for prioritisation of sites.

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APPENDIX 1

FIELDS IN THE WILDING CONIFER SITE DATABASE

<table>
<tr><th>Field</th><th>Notes</th></tr>
<tr><td>Id</td><td>Sequential site numbers 1-563 (site 326 missing)</td></tr>
<tr><td>Reviewed</td><td></td></tr>
<tr><td>Island</td><td>North, South (smaller islands included in mainland)</td></tr>
<tr><td>Group</td><td>Mixture of DOC offices, Regional and District councils, LINZ</td></tr>
<tr><td>Site name_original</td><td>Non-unique site name e.g. Arthurs Point, Waitaanga, Walter Peak</td></tr>
<tr><td>Contact person</td><td>One contact, listed person sometimes refers to someone else</td></tr>
<tr><td>Location (GPS or Grid) NZTM</td><td>Incomplete, mixture of formats, some coordinates incorrect</td></tr>
<tr><td>Site name_sub</td><td>Non-unique site name e.g. Arthurs Point, Waitaanga, Walter Peak</td></tr>
<tr><td>Region</td><td>Mixture of regions, districts, councils, quadrants of North and South islands</td></tr>
<tr><td>Sub region</td><td>Incomplete. 8 central NI sub regions only</td></tr>
<tr><td>Species</td><td>Conifer species present. Some other species included at some sites</td></tr>
<tr><td>approx ha Dense</td><td>Estimated area of dense wildings (ha), range 0-33,112, plus unknown</td></tr>
<tr><td>aprox ha Sparse</td><td>Estimated area of sparse wildings (ha), range 0-72,216, plus unknown</td></tr>
<tr><td>Proposed Management Approach</td><td>
<table>
<tr><th>Management Objective</th><th>Criteria</th></tr>
<tr><td>Exclusion</td><td>Zero density, high value of land’s current state, cost-effective to exclude, risk of invasion.</td></tr>
<tr><td>Eradication/ Containment</td><td>Ability to remove all individuals, low-risk of reinvasion, ability to recover site to desired outcome, an area which benefits.</td></tr>
<tr><td>Progressive containment</td><td>Defendable boundaries, feasible to remove sources or stop further spread, long term funding for knockdown and ongoing maintenance.</td></tr>
<tr><td>Containment / Sustained control</td><td>Integrated pest management outcomes, externality impacts, widely distributed, long term funding commitment, occupies almost all suitable habitat.</td></tr>
</table>
</td></tr>
<tr><td>Approximate cost to achieve control approach in 5 year period</td><td>Range $60-$8,000,000</td></tr>
<tr><td>Programme underway</td><td>Y, N</td></tr>
<tr><td>Parties involved (list all)</td><td>Community (Iwi)
Department of Conservation (DOC)
Land Information NZ (LINZ)
NZ Defence Force (NZDF)
Regional Councils (RC)
Territorial Local Authorities (TLA)
Other (Other)</td></tr>
<tr><td>Siting</td><td>
<table>
<tr><td>a</td><td>Sheltered sites, or slopes facing away from strong/prevalent winds.</td></tr>
<tr><td>b</td><td>Sites partially exposed to strong/prevalent winds (often from N & W - 200o to 45o).</td></tr>
<tr><td>c</td><td>Sites partially exposed to strong/prevalent winds.</td></tr>
<tr><td>d</td><td>take off' site - i.e. Ridgetops, on or at base of slopes (>10o) or undulating land fully exposed to strong/prevalent winds.</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Downwind land use</td><td><table>
<tr><td>a</td><td>Developed pasture/regular mob stocking (sheep) or closed canopy scrub/forest.</td></tr>
<tr><td>b</td><td>Semi improved (some fertiliser used in past), sheep grazing/ occasional mob stocking.</td></tr>
<tr><td>c</td><td>Extensive grazing only.</td></tr>
<tr><td>d</td><td>No grazing.</td></tr>
</table></td></tr>
<tr><td>Downwind vegetation</td><td><table>
<tr><td>a</td><td>Developed pasture, rank grass, closed canopy forest.</td></tr>
<tr><td>b</td><td>Shrubland/tussock/grassland with a continuous and heavy vegetation cover.</td></tr>
<tr><td>c</td><td>Forest/shrubland/tussock/grassland with few gaps.</td></tr>
<tr><td>d</td><td>Open forest and/or sparse patches of dense shrubland/tussock/ grassland with many gaps.</td></tr>
<tr><td>e</td><td>Open slips/rockland and/or light, low-stature shrubland/tussock/ grassland.</td></tr>
</table></td></tr>
<tr><td>Rough estimate of area at risk of invasion</td><td>Area in hectares (range 0-215,000)</td></tr>
<tr><td>Notes rough estimate of area at risk</td><td>Few notes provided (four sites only)</td></tr>
<tr><td>Types of values at risk (list)</td><td><table>
<tr><td>Economic (Ec)</td><td>Maintenance of specific land-use productivity, direct risk to human livelihood, minimisation of direct off-site effects.</td></tr>
<tr><td>Environmental (En)</td><td>Biodiversity (protect ecosystem or particular species), maintenance of current natural resource mix.</td></tr>
<tr><td>Social (So)</td><td>Maintenance of landscape appearance, social/ community impact.</td></tr>
</table></td></tr>
<tr><td>Source land (crown private or both)</td><td>Land ownership - crown, private, or both.</td></tr>
<tr><td>Receiving Land (crown private or both)</td><td>Land ownership - crown, private, or both.</td></tr>
<tr><td>Source pre or post 1990</td><td>Pre, Post</td></tr>
<tr><td>Other Comments</td><td>Wide range of comments on past control, site values, sources of information etc.</td></tr>
<tr><td>DSS1 Tots</td><td>Scores based on DSS1 assessment.</td></tr>
<tr><td>No Risk</td><td>Uncertain what this applies to.</td></tr>
</table>

EXPERTS WHO RESPONDED TO THE WILDING CONIFER QUESTIONNAIRE

Expert	Role	Wilding Conifer Experience	
		Years	Areas
Nick Ledgard	Scientist	30	All of New Zealand
Alan Mark	Scientist	20	Otago, Southland, Canterbury
Andrew McAlister	Manager	7	Nelson-Marlborough
Brad Lett	Operations	15	Central North Island
Clayson Howell	Scientist	8	Otago, Canterbury, Central NI
Colin Day	Operations	5	Otago, Southland
Craig Davey	Manager	12	Central North Island
Dean Turner	Operations	17	Canterbury
James Kilgour	Operations	8	Canterbury, Nelson/Marlborough
Graeme Omlo	Manager	35	Nelson/Marlborough
Ian Cox	Operations	25	Nelson/Marlborough
Jono Underwood	Manager	6	Nelson/Marlborough
Larry Burrows	Scientist	30	All of New Zealand
Leith Rhynd	Operations	28	Central North Island
Paul Hondelink	Operations	40	Otago
Patrik Eschenmoser	Operations	8	Otago
Pete Raal	Operations	15	All of New Zealand
Peter Willsman	Manager	8	Otago, Southland
Ray Goldring	Manager	6	Canterbury
Richard Bowman	Manager	15	Otago, Southland
Richard Heyward	Operations	2	Otago
Wayne Godfrey	Operations	11	South Island
Willie Shaw	Scientist	30	Otago, Canterbury, Nelson/ Marlborough, Central NI
Kelvin Lloyd	Scientist	15	South Island
Shane Grayling	Manager	3	Bay of Plenty
Pete Willemse	Manager	14	Southland, Canterbury

